SBE 16*plus* SEACAT

Conductivity and Temperature Recorder (pressure optional) with RS-232 Interface

User's Manual

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Manual Version #017, 07/19/07
Firmware Version 1.8c and later
SEASAVE V7 Version 7.12 and later

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Section 1: Introduction

This section includes contact information, Quick Start procedure, and photos of a standard SBE 16*plus* shipment.

About this Manual

This manual is to be used with the SBE 16*plus* SEACAT Conductivity and Temperature (pressure optional) Recorder.

It is organized to guide the user from installation through operation and data collection. We have included detailed specifications, command descriptions, maintenance and calibration information, and helpful notes throughout the manual.

Sea-Bird welcomes suggestions for new features and enhancements of our products and/or documentation. Please e-mail any comments or suggestions to seabird@seabird.com.

How to Contact Sea-Bird

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(1600 to 0100 Universal Time)
Except from April to October, when we are on *summer time*
(1500 to 0000 Universal Time)

Quick Start

Follow these steps to get a Quick Start using the SBE 16*plus*.
The manual provides step-by-step details for performing each task:

1. Install batteries and test power and communications (see *Section 3: Power and Communications Test*).

2. Deploy the 16*plus* (see *Section 4: Deploying and Operating SBE 16plus*):
   A. Install new batteries if necessary.
   B. Ensure all data has been uploaded, and then send **InitLogging** to make entire memory available for recording if desired.
   C. Set date and then time and establish setup and logging parameters.
   D. Set 16*plus* to start logging now or in the future.
   E. Install dummy plugs and/or cable connectors, and locking sleeves.
   F. Remove protective plugs from anti-foulant device cups, and verify AF24173 Anti-Foulant Devices are installed. Leave protective plugs off for deployment.
   G. Deploy 16*plus*, using customer-supplied hardware.

Unpacking SBE 16*plus*

Shown below is a typical SBE 16*plus* shipment.

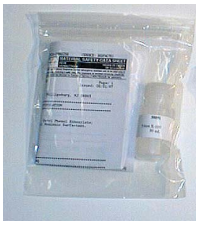
SBE 16*plus* SEACAT
(shown in both plastic and titanium housing)

I/O Cable

25-pin to 9-pin adapter
(for use with computer
with DB-25 connector)

Spare o-ring and
hardware kit

Conductivity cell filling
and storage kit



Conductivity cell cleaning
solution (Triton-X)

SBE 16*plus* manual

Software, and Electronic Copies of
Software Manuals and User Manual

Section 2: Description of SBE 16*plus*

This section describes the functions and features of the SBE 16*plus* SEACAT, including:

- system description
- specifications
- dimensions and end cap connectors
- communication settings
- data storage
- batteries and battery endurance
- external power and cable length limitations
- configuration options and plumbing

System Description

The SBE 16*plus* SEACAT is designed to measure conductivity, temperature, and (optional) pressure in marine or fresh-water environments in moored applications at depths up to 10,500 meters (34,400 feet). The 16*plus* operates as follows:

- **Autonomous sampling** - The 16*plus* can acquire and record in memory time series measurements at sample rates of once every 10 seconds to once every 4 hours, adjustable in one-second increments. Between samples, the 16*plus* powers down, drawing only 30 microamps of current. Simultaneous, real-time data transmission is possible using the 16*plus* three-wire RS-232C interface.
- **Polled sampling** – A surface controller can request the last sample that was taken or ask the 16*plus* to take a new sample. Data is transmitted over the RS-232 interface.
- **Serial line sync** – The 16*plus* wakes up, samples, stores data in memory, transmits real-time data (if enabled), and powers off in response to a pulse on the serial line. This provides an easy method for synchronizing 16*plus* sampling with other instruments such as Acoustic Doppler Current Profilers (ADCPs) or current meters, without drawing on their battery or memory resources.

Self-powered and self-contained, the SBE 16*plus* features the proven Sea-Bird conductivity and temperature sensors. Nine D-size alkaline batteries provide power for approximately 380,000 samples (with no internally mounted pressure sensor, pump, or auxiliary sensors). The 8 Mbyte FLASH RAM memory records 1.5 years of conductivity, temperature, and date/time data while sampling every 60 seconds (other configurations/setups vary). User-selectable output format is raw data or engineering units, in hexadecimal or decimal form. Setup, diagnostics, and data extraction are performed without opening the housing. The 16*plus* can power external sensors and acquire their outputs.

A standard SBE 16*plus* is supplied with:

- Plastic housing for depths to 600 meters (1950 feet)
- Bulkhead connectors (Impulse glass-reinforced epoxy):
  - one 4-pin I/O connector,
  - one 2-pin pump connector, and
  - two 6-pin connectors, for two differential auxiliary A/D inputs each
- 8 Mbyte FLASH RAM memory
- 9 D-size alkaline batteries (Duracell MN1300, LR20)
- Anti-foulant device attachments and expendable AF24173 Anti-Foulant Devices. These are attached to each end of the conductivity cell, so that any water that enters the cell is treated.

SBE 16*plus* options include:

- Titanium housing for use to 7000 or 10500 meters (22,900 or 34,440 feet)
- Internally mounted pressure sensor -
  - Strain gauge pressure sensor, or
  - Quartz pressure sensor
- Additional bulkhead connector: 4-pin RS-232 connector (for SBE 38 secondary temperature sensor, SBE 50 pressure sensor, or up to two Pro-Oceanus Gas Tension Devices) **or** 3-pin PAR connector
- Pump -
  - SBE 5M (available in plastic or titanium housing) for pumped conductivity, or
  - SBE 5P (plastic housing) or 5T (titanium housing) for pumped conductivity **and** pumped auxiliary sensors
- Sensors for dissolved oxygen, fluorescence, light (PAR), light transmission, turbidity, and gas tension
- Wet-pluggable (MCBH) connectors in place of standard connectors
- RS-485 interface in place of RS-232. See the *SBE 16plus SEACAT (RS-485) Manual*.
- **I**nductive **M**odem (IM) interface in place of RS-232 - The inductive modem uses a mooring cable as the communication link, permitting the SBE 16*plus*-IM to be easily positioned at any depth without the use of cable connectors. Each inductive modem instrument has a programmable address, allowing up to 100 SBE 16*plus*-IM SEACATs (or other sensors compatible with the Sea-Bird inductive modem) to be attached to a single mooring cable. See the *SBE 16plus-IM SEACAT Manual*.
- Battery pack kit for lithium batteries for longer deployments (lithium batteries **not** supplied by Sea-Bird).

Notes:

- Help files provide detailed information on the use of SEATERM, SEASAVE V7, and SBE Data Processing.
- Separate software manuals contain detailed information on the setup and use of SEASAVE V7 and SBE Data Processing.
- Sea-Bird also supplies an older version of SEASAVE, SEASAVE-Win32. However, all SEASAVE instructions in this manual are written for SEASAVE V7. See SEASAVE-Win32's manual and/or Help files if you prefer to use the older software.

The SBE 16*plus* is supplied with a powerful Win 2000/XP software package, SEASOFT-Win32, which includes:

- **SEATERM** – terminal program for easy communication and data retrieval.
- **SEASAVE V7** – program for acquiring, converting, and displaying real-time or archived raw data.
- **SBE Data Processing** – program for calculation and plotting of conductivity, temperature, pressure, auxiliary sensor data, and derived variables such as salinity and sound velocity.

Specifications

	Temperature (°C)	Conductivity (S/m)	Internally Mounted Pressure (optional)
Measurement Range	-5 to +35	0 to 9	0 to full scale range: • *Strain gauge sensor:* 20 / 100 / 350 / 600 / 1000 / 2000 / 3500 / 7000 meters • *Quartz sensor:* 20 / 60 / 130 / 200 / 270 / 680 / 1400 / 2000 / 4200 / 7000 / 10500 meters
Initial Accuracy	0.005	0.0005	• *Strain gauge sensor:* 0.1% of full scale range • *Quartz sensor:* 0.02% of full scale range
Typical Stability (per month)	0.0002	0.0003	• *Strain gauge sensor:* 0.004% of full scale range • *Quartz sensor:* 0.002% of full scale range
Resolution	0.0001	• 0.00005 (most oceanic water; resolves 0.4 ppm in salinity). • 0.00007 (high salinity water; resolves 0.4 ppm in salinity). • 0.00001 (fresh water; resolves 0.1 ppm in salinity).	• *Strain gauge sensor:* 0.002% of full scale range • *Quartz sensor:* Depends on sample integration time (see notes below)
Sensor Calibration (measurement outside these ranges may be at slightly reduced accuracy due to extrapolation errors)	+1 to +32	0 to 9; physical calibration over range 2.6 to 6 S/m, plus zero conductivity (air)	Ambient pressure to full scale range in 5 steps

***Notes on Internally Mounted Quartz Pressure Sensor Resolution:**

Resolution = Sensitivity * Counter Resolution

- Counter Resolution = frequency at depth of interest / (**ParosIntegration** * 1,228,800)
  where **ParosIntegration** = user-input integration time (seconds)
- Sensitivity = Δ pressure at depth of interest / Δ frequency at depth of interest
  where Δ pressure is change in pressure in desired units (psia, db, meters, etc.)
  Δ frequency is change in frequency in Hz
- To convert pressure units: db = psia / 1.45

Example:
For a 7000 meter (10,000 psia) Quartz pressure sensor, what resolution can be obtained at depth?

Test data for a sample 7000 meter sensor shows:
At 6896 db, output frequency = 36,500 Hz
At 7131.9 db, output frequency = 36,600 Hz

Δ pressure at depth of interest = 7131.9 db – 6896 db = 235.9 db
Δ frequency at depth of interest = 36,600 Hz – 36,500 Hz = 100 Hz
Sensitivity = Δ pressure at depth of interest / Δ frequency at depth of interest = 235.9 db / 100 Hz = 2.359 db / Hz

Counter Resolution = frequency at depth of interest / (**ParosIntegration** * 1,228,800) =
36,500 Hz / (**ParosIntegration** * 1,228,800)

Resolution = Sensitivity * Counter Resolution = 2.359 db/Hz * 36,500 Hz / (**ParosIntegration** * 1,228,800)
Looking at the resolution at depth that can be obtained with a range of values for the integration time:

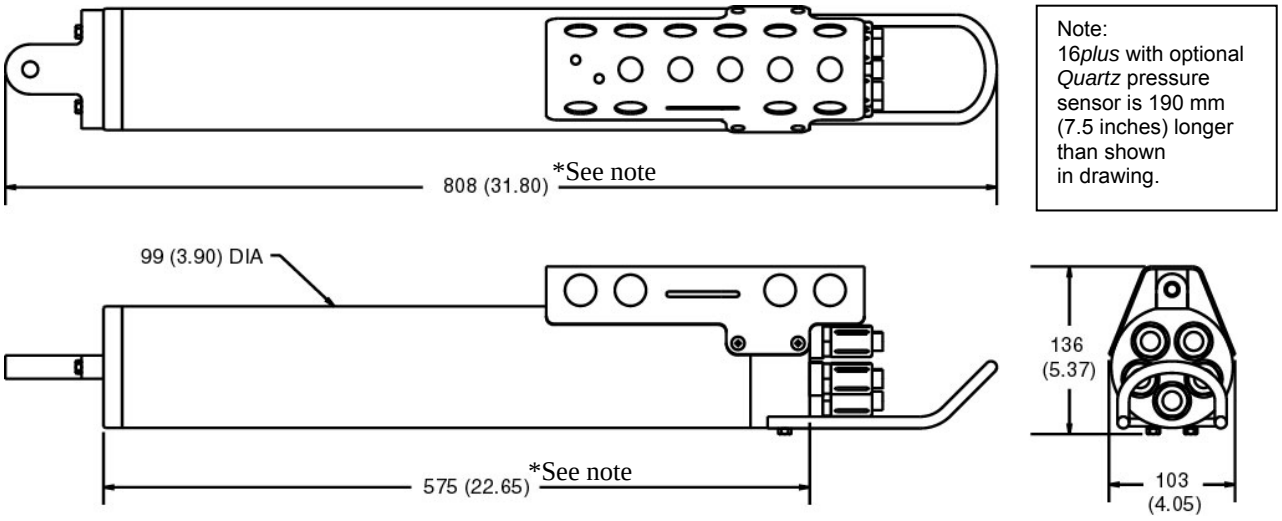
Integration time (ParosIntegration=)	Resolution
1 second	0.07 db (70 mm)
1.4 seconds	0.05 db (50 mm)
7 seconds	0.01 db (10 mm)
70 seconds	0.001 db (1 mm)

<table>
<tr><td>Memory</td><td>8 Mbyte non-volatile FLASH memory</td></tr>
<tr><td>Data Storage</td><td>
<table>
<tr><th><u>Recorded Parameter</u></th><th><u>Bytes/sample</u></th></tr>
<tr><td>temperature + conductivity</td><td>6 (3 each)</td></tr>
<tr><td>internally mounted strain gauge pressure</td><td>5</td></tr>
<tr><td>internally mounted Quartz pressure with temperature compensation</td><td>6</td></tr>
<tr><td>each external voltage</td><td>2</td></tr>
<tr><td>SBE 38 secondary temperature</td><td>3</td></tr>
<tr><td>SBE 50 pressure</td><td>3</td></tr>
<tr><td>each Pro-Oceanus GTD</td><td>4 (pressure) + 3 (temperature)</td></tr>
<tr><td>date and time</td><td>4</td></tr>
</table>
</td></tr>
<tr><td>Real-Time Clock</td><td>32,768 Hz TCXO accurate to ±1 minute/year.</td></tr>
<tr><td>Internal Batteries</td><td>Nine alkaline D-cells (Duracell MN 1300, LR20; nominal capacity 14 amp-hours).</td></tr>
<tr><td>External Power Supply</td><td>9 - 28 VDC; current requirement varies, depending on voltage and pump:
• 3 Amps at 9V input - no pump or SBE 5M pump (cannot use SBE 5P or 5T with 9V input)
• 0.5 Amps at 12V input – no pump or SBE 5M pump
• 3 Amps at 12V input – SBE 5P or 5T pump
• 0.25 Amps at 19V input – no pump
• 0.5 Amps at 19V input – SBE 5M pump
• 1.5 Amps at 19V input – SBE 5P or 5T pump</td></tr>
<tr><td>Power Requirements</td><td>
<table>
<tr><td>Sampling:</td><td>no pressure sensor</td><td>50 mA</td></tr>
<tr><td></td><td>with internally mounted pressure</td><td>65 mA</td></tr>
<tr><td>Optional Pump:</td><td>SBE 5M</td><td>100 mA</td></tr>
<tr><td></td><td>SBE 5P or 5T</td><td>150 mA</td></tr>
<tr><td>Communications:</td><td></td><td>60 mA</td></tr>
<tr><td>Quiescent:</td><td></td><td>30 μA</td></tr>
</table>
Sampling time:
• Minimum 2.2 seconds/sample (no pump, no internally mounted pressure sensor, 1 measurement/sample, and no delays).
• Add 0.3 seconds with internally mounted strain gauge pressure sensor.
• Add integration time with internally mounted Quartz pressure sensor (ParosIntegration=; minimum 1 second).
• Add 0.25 seconds for each additional measurement/sample (NCycles <u>≥</u> 2).
• Add pump on-time (0.5 second) if pump running before taking sample (PumpMode=1).
• Add time for user-programmed delay before sampling (DelayBeforeSampling=).

Approximate Battery Endurance [1]:
CT: 380,000 samples
CTD: 260,000 samples
CTD & 5M pump: 145,000 samples
[1] With Duracell MN 1300 (LR20) cells. Dependent on sampling scheme; see Battery Endurance for example calculations.</td></tr>
<tr><td>Auxiliary Voltage Sensors</td><td>Auxiliary power out: up to 500 mA at 10.5 - 11 VDC
A/D resolution: 14 bits
Input range: 0 - 5 VDC</td></tr>
<tr><td>Housing Depth Range and Materials</td><td>600 meter (1950 ft): acetal copolymer (plastic)
7000 meter (22,900 ft): 3AL-2.5V titanium
10,500 meter (34,400 ft): 6AL-4V titanium</td></tr>
<tr><td>Weight (without pump)</td><td>With plastic housing:
in air 7.3 kg (16 lbs) in water 2.3 kg (5 lbs)
With 3AL-2.5V titanium housing:
in air 13.7 kg (30 lbs) in water 8.6 kg (19 lbs)</td></tr>
</table>

Dimensions and End Cap Connectors

Dimensions in millimeters (inches)



Note:
16*plus* with optional *Quartz* pressure sensor is 190 mm (7.5 inches) longer than shown in drawing.

Optional RS-232 Connector

Pin	Signal
1	Common
2	RS-232 Data transmit to RS-232 sensor
3	RS-232 Data receive from RS-232 sensor
4	Power to RS-232 sensor

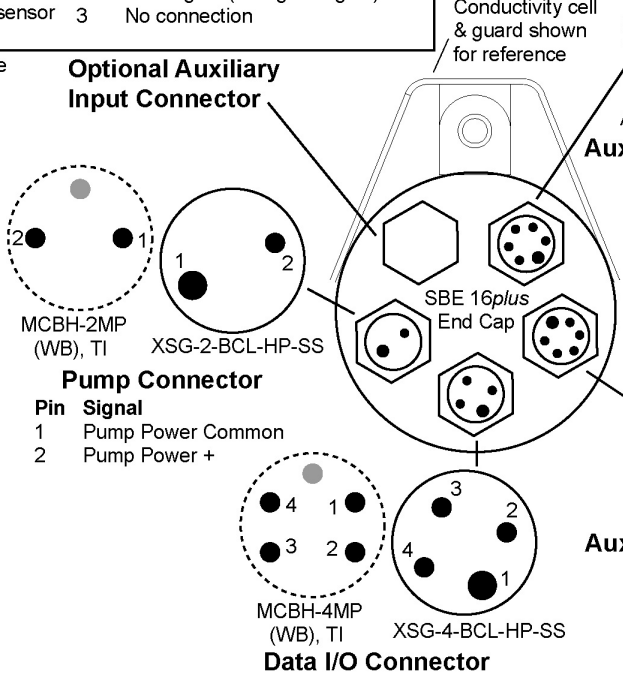
Optional PAR Connector

Pin	Signal
1	PAR common (voltage 3 common)
2	PAR signal (voltage 3 signal)
3	No connection

Note: RS-232 sensor must be set to same baud rate as 16*plus*.

= standard connector

= optional MCBH connector (all with 3/8" length base, 1/2-20 thread)



Pump Connector

Pin	Signal
1	Pump Power Common
2	Pump Power +

Auxiliary Differential Input 0,1

Pin	Signal
1	Common
2	Voltage 0 Signal
3	Voltage 0 Common
4	Voltage 1 Signal
5	Voltage 1 Common
6	Auxiliary Power Out

Data I/O Connector

Pin	Signal
1	Common
2	RS-232 data receive
3	RS-232 data transmit
4	Auxiliary power in (9-28 VDC)

Auxiliary Differential Input 2,3

Pin	Signal
1	Common
2	Voltage 2 Signal
3	Voltage 2 Common
4	Voltage 3 Signal *
5	Voltage 3 Common *
6	Auxiliary Power Out

* Not connected if log amp installed for PAR sensor

Data I/O

The SBE 16*plus* receives setup instructions and outputs diagnostic information or previously recorded data via a three-wire RS-232C link, and is factory-configured for 9600 baud, 8 data bits, 1 stop bit, and no parity. SBE 16*plus* RS-232 levels are directly compatible with standard serial interface cards (IBM Asynchronous Communications Adapter or equal). The communications baud rate can be changed using **Baud=** (see *Command Descriptions* in *Section 4: Deploying and Operating SBE 16plus*).

Data Storage

Note:
See *Battery Endurance* for power limitations.

The SBE 16*plus* has an 8 Mbyte FLASH memory. If the memory is filled to capacity, data sampling and transmission of real-time data (if programmed) continue, but excess data is not saved in memory.

Shown below are examples of available data storage for several configurations. See *Specifications* for storage space required for each parameter.

Example 1: internally mounted strain gauge pressure and no auxiliary sensors
T & C = 6 bytes/sample
Internally mounted strain gauge P = 5 bytes/sample
Date/Time = 4 bytes/sample
Storage space ≈ 8,000,000 / (6 + 5 + 4) ≈ 533,000 samples

Example 2: internally mounted Quartz pressure, 4 external voltages, and SBE 38 secondary temperature sensor
T & C = 6 bytes/sample
Internally mounted Quartz P = 6 bytes/sample
External voltages = 2 bytes/sample * 4 voltages = 8 bytes/sample
SBE 38 = 3 bytes/sample
Date/Time = 4 bytes/sample
Storage space ≈ 8,000,000 /(6 + 6 + 8 + 3 + 4) ≈ 296,000 samples

Batteries

For the main battery, the SBE 16*plus* uses nine D-cell alkaline batteries (Duracell MN 1300, LR20). If necessary, lithium, carbon-zinc, or mercury cells can also be used.

On-board lithium batteries (non-hazardous units which are unrestricted for shipping purposes) are provided to back-up the buffer and the real-time clock in the event of main battery failure or exhaustion. The main batteries may be replaced without affecting either the real-time clock or memory.

Battery Endurance

Notes:
- If the 16*plus* is logging data and the battery voltage is less than 7.5 volts, the 16*plus* halts logging and displays a low battery indication in the data.
- See *Data Storage* and *Specifications* for data storage limitations.

The standard alkaline battery pack has a nominal capacity of 14 amp-hours. For planning purposes, Sea-Bird recommends using a conservative value of:
- 12.2 amp-hours for an SBE 16*plus* with no pump or auxiliary sensors
- 10.5 amp-hours for an SBE 16*plus* drawing more current because of optional pump and/or auxiliary sensors

Current consumption and sampling times vary greatly, depending on the instrument configuration (inclusion of pressure sensor, pump, and/or auxiliary sensors) as well as user-programmed sampling parameters (pump operating mode, number of measurements per sample, delay before sampling, quartz pressure sensor integration time). Examples are shown below for several sampling schemes.

A 16*plus* with standard alkaline batteries is set up to sample autonomously every 10 minutes (6 samples/hour). How long can it be deployed?

Example 1 – no pump, internally mounted pressure sensor, or auxiliary sensors; 1 measurement/sample (**NCycles=1**)*:*

Sampling current = 50 mA * 2.2 sec = 0.11 amp-sec/sample
In 1 hour, sampling current = 6 * 0.11 amp-sec/sample = 0.66 amp-sec/hour

Quiescent current = 30 microamps = 0.03 mA
In 1 hour, quiescent current ≈ 0.03 mA * 3600 sec/hour = 0.108 amp-sec/hour

Current consumption / hour = 0.66 + 0.108 = 0.768 amp-sec/hour
Capacity = (12.2 amp-hours * 3600 sec/hr) / (0.768 amp-sec/hour) = 57187 hours = 2382 days = 6.5 years
However, Sea-Bird recommends that batteries should not be expected to last longer than 2 years in the field.

Example 2 - with 5M pump on for 0.5 sec/sample (**PumpMode=1**), no internally mounted pressure sensor or auxiliary sensors, 1 measurement/sample (**NCycles=1**)*:*

Sampling current = 50 mA * (2.2 sec + 0.5 sec) = 0.135 amp-sec/sample
In 1 hour, sampling current = 6 * 0.135 amp-sec/sample = 0.81 amp-sec/hour

Pump current = 100 mA * 0.5 sec = 0.05 amp-sec/sample
In 1 hour, pump current = 6 * 0.05 amp-seconds/sample = 0.30 amp-sec/hour

Quiescent current = 30 microamps = 0.03 mA
In 1 hour, quiescent current ≈ 0.03 mA * 3600 sec/hour = 0.108 amp-sec/hour

Current consumption / hour = 0.81 + 0.30 + 0.108 = 1.22 amp-sec/hour
Capacity = (10.5 amp-hours * 3600 sec/hr) / (1.22 amp-sec/hour) = 30983 hours = 1290 days = 3.5 years
However, Sea-Bird recommends that batteries should not be expected to last longer than 2 years in the field.

Example 3 - with 5T pump on during sample (**PumpMode=2**), 15 sec delay before sampling (**DelayBeforeSampling=15**), internally mounted Quartz pressure sensor integrating for 3 sec/sample (**ParosIntegration=3**), auxiliary sensors drawing 100 mA, 4 measurements/sample (**NCycles=4**):

On-time = 2.2 + 3 (Quartz integration) + 15 (delay before sampling) + (4 – 1) * 0.25 (additional measurements/sample)
= 20.95 sec
Sampling current = 65 mA * 20.95 sec = 1.36 amp-sec/sample
In 1 hour, sampling current = 6 * 1.36 amp-sec/sample = 8.2 amp-sec/hour

5T Pump current = 150 mA * 20.95 sec = 3.14 amp-sec/sample
In 1 hour, pump current = 6 * 3.14 amp-sec/sample = 18.9 amp-sec/hour

Auxiliary sensor current = 100 mA * 20.95 sec = 2.10 amp-sec/sample
In 1 hour, auxiliary sensor current = 6 * 2.10 amp-sec/sample = 12.6 amp-sec/hour

Quiescent current = 30 microamps = 0.03 mA
In 1 hour, quiescent current ≈ 0.03 mA * 3600 sec/hour = 0.108 amp-sec/hour

Current consumption / hour = 8.2 + 18.9 + 12.6 + 0.108 = 39.8 amp-sec/hour
Capacity = (10.5 amp-hours * 3600 sec/hr) / (39.8 amp-sec/hour) = 950 hours = 39 days = 0.11 years

External Power

The SBE 16*plus* can be powered from an external source (9 - 28 volts DC) through the I/O bulkhead connector on the sensor end cap. The internal battery pack is diode-OR'd with the external source, so power will be drawn from whichever voltage source is higher. The 16*plus* can also be operated from the external supply without having the internal battery pack installed. Electrical isolation of conductivity is retained in units powered externally, preventing ground loop noise contamination in the conductivity measurement.

Cable Length and External Power

Note:
See *Real-Time Setup* in *Section 4: Deploying and Operating SBE 16plus* for baud rate limitations on cable length if transmitting real-time data.

There are two issues to consider if powering the SBE 16*plus* externally:
- Limiting the communication IR loss to 1 volt **if transmitting real-time data**; higher IR loss will prevent the instrument from transmitting real-time data because of the difference in ground potential.
- Supplying enough power at the power source so that sufficient power is available at the instrument after considering IR loss.

Each issue is discussed below.

Note:
Common wire resistances:

Gauge	Resistance (ohms/foot)
12	0.0016
14	0.0025
16	0.0040
18	0.0064
19	0.0081
20	0.0107
22	0.0162
24	0.0257
26	0.0410
28	0.0653

Limiting Communication IR Loss to 1 Volt if Transmitting Real-Time Data

The limit to cable length is typically reached when the maximum ***communication*** current times the power common wire resistance is more than 1 volt, because the difference in ground potential of the SBE 16*plus* and ground controller prevents the 16*plus* from transmitting real-time data.

V_{limit} = 1 volt = IR_{limit}

Maximum cable length = R_{limit} / wire resistance per foot

where I = communication current required by SBE 16*plus* (60 milliamps; see *Specifications*).

Example 1 – For 20 gauge wire, what is maximum distance to transmit power to 16*plus* if transmitting real-time data?
For 60 milliamp communications current, $R_{limit} = V_{limit} / I$ = 1 volt / 0.060 Amps = 16.7 ohms
For 20 gauge wire, resistance is 0.0107 ohms/foot.
Maximum cable length = 16.7 ohms / 0.0107 ohms/foot = 1557 feet = 474 meters

Example 2 – Same as above, but there are 4 instruments powered from the same power supply.
For 60 milliamp communications current, $R_{limit} = V_{limit} / I$ = 1 volt / (0.060 Amps * 4 instruments) = 4.1 ohms
Maximum cable length = 4.1 ohms / 0.0107 ohms/foot = 389 feet = 118 meters (to 16*plus furthest* from power source).

Supplying Enough Power to SBE 16plus

Another consideration in determining maximum cable length is supplying enough power at the power source so that sufficient voltage is available, after IR loss in the cable (***from the turn-on transient, two-way resistance***), to power the SBE 16*plus*. The table summarizes the maximum 2-way resistance for various input supplies and pump configurations:

Power Supply Input and Pump Configuration	**R_{limit} = Maximum 2-way Resistance (ohms)**
3 Amps at 9V input, no pump or SBE 5M pump (cannot use SBE 5P or 5T with 9V input)	1
0.5 Amps at 12V input, no pump	50
0.5 Amps at 12V input, SBE 5M pump	10
3.0 Amps at 12V input, SBE 5P or 5T pump	2
0.25 Amps at 19V input, no pump	150
0.5 Amps at 19V input, SBE 5M pump	30
1.5 Amps at 19V input, SBE 5P or 5T pump	7

Calculate maximum cable length as:

Maximum cable length = R_{limit} / 2 * wire resistance per foot

Example 1 – For 20 gauge wire, what is maximum distance to transmit power to 16*plus* if using 12 volt power source with SBE 5T pump?
Maximum cable length = R_{limit} / 2 * wire resistance per foot = 2 ohms / 2 * 0.0107 ohms/foot = 93 ft = 28 meters
Note that 28 meters < 474 meters (maximum distance if 16*plus* is transmitting real-time data), so IR drop in power is controlling factor for this example. Using a higher voltage power supply or a different wire gauge would increase allowable cable length.

Example 2 – Same as above, but there are 4 instruments powered from same power supply.
Maximum cable length = R_{limit} / 2 * wire resistance per foot * 4 instruments
= 2 ohms / 2 * 0.0107 ohms/foot * 4 = 23 ft = 7 meters (to 16*plus furthest* from power source)

Configuration Options and Plumbing

The SBE 16*plus* is available with an optional, externally mounted, submersible pump. The pump is required for a 16*plus* configured with an optional dissolved oxygen sensor or pumped fluorometer, but also provides the following benefits for conductivity data:

- Improved conductivity response - The pump flushes the previously sampled water from the conductivity cell and brings a new water sample quickly into the cell.

- Improved anti-foulant protection - Water does not freely flow through the conductivity cell between samples, allowing the anti-foulant concentration inside the cell to build up.

Several pump models are available:

- SBE 5M miniature pump (available in plastic or titanium) - for pumped conductivity.

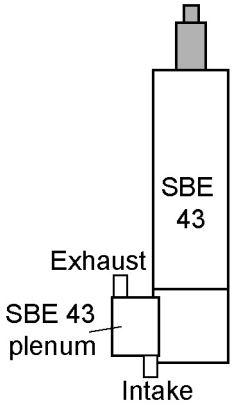
- SBE 5P (plastic) or 5T (titanium) pump - a more powerful pump for use if the SBE 16*plus* is configured with a dissolved oxygen sensor and/or pumped fluorometer.

In all cases, the pump is powered via a cable connected to the standard 2-pin Pump bulkhead connector on the sensor end cap.

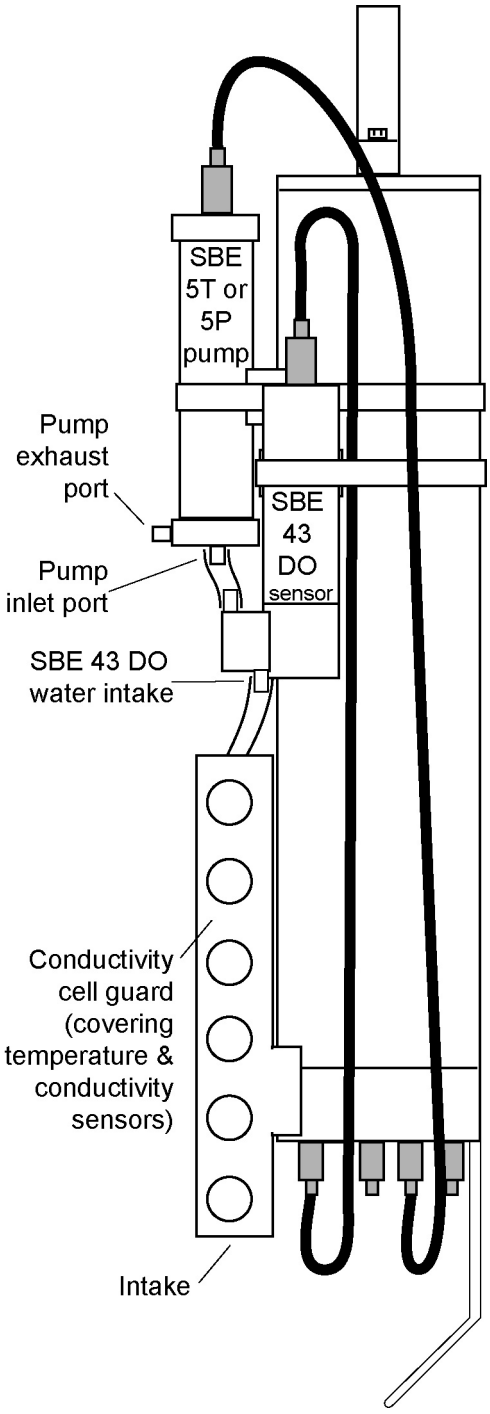
The SBE 16*plus* can be configured with a wide range of auxiliary sensors. Two standard 6-pin bulkhead connectors on the sensor end cap serve as the input ports for the auxiliary sensor signal voltages and provide power to the sensors. Additionally, an optional connector can be provided for interfacing with an RS-232 sensor, such as an SBE 38 secondary temperature sensor, an SBE 50 strain-gauge pressure sensor, or Pro-Oceanus Gas Tension Devices (up to two GTDs can be integrated with the 16*plus*), or an optional connector can be provided for interfacing with a PAR sensor.

Shown below is the plumbing arrangement of an SBE 16*plus* equipped with a pump and the optional SBE 43 Dissolved Oxygen sensor. See *Section 4: Deploying and Operating SBE 16plus* for pump setup and operation details.

- Main plumbing is 13 mm ID x 19 mm OD (1/2 inch x 3/4 inch) Tygon tubing.
- A 13 mm (0.5 inch) long piece of 9.5 mm ID x 13 mm OD (3/8 inch x 1/2 inch) Tygon tubing to fit to the main plumbing is installed:
  - on the conductivity cell exhaust, and
  - on the SBE 43 intake and exhaust



Place DO sensor with plenum intake closer than exhaust to SBE 43 housing, as shown.
Note: SBE 43 housing orientation (connector end up or down) does not affect operation. Plenum can be reversed on housing by removing and replacing 2 screws.



Section 3:
Power and Communications Test

This section describes installing software and the pre-check procedure for preparing the SBE 16*plus* for deployment. The power and communications test will verify that the system works, prior to deployment.

Software Installation

Sea-Bird recommends the following minimum system requirements for SEASOFT-Win32: Windows 2000 or later, 500 MHz processor, 256 MB RAM, and 90 MB free disk space for installation.

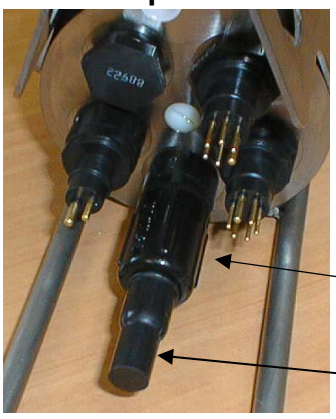
Note:
It is possible to use the 16*plus* without SEATERM by sending direct commands from a dumb terminal or terminal emulator, such as Windows HyperTerminal.

If not already installed, install SEATERM and other Sea-Bird software programs on your computer using the supplied software CD:

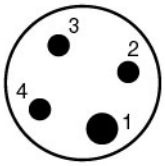
1. Insert the CD in your CD drive.
2. Double click on **Seasoft-Win32.exe**.
3. Follow the dialog box directions to install the software.

The default location for the software is c:/Program Files/Sea-Bird. Within that folder is a sub-directory for each program. The installation program allows you to install the desired components. Install all the components, or just install SEATERM (terminal program), SEASAVE V7, and SBE Data Processing.

Test Setup



1. Remove the dummy plug and install the I/O cable:
   A. By hand, unscrew the locking sleeve from the 16*plus* I/O (4-pin) connector. If you must use a wrench or pliers, be careful not to loosen the I/O connector instead of the locking sleeve.
   B. Remove the dummy plug from the 16*plus* I/O connector by pulling the plug firmly away from the connector.
   C. **Standard Connector** - Install the I/O cable connector, aligning the raised bump on the side of the connector with the large pin (pin 1 - ground) on the 16*plus*. **OR**
   MCBH Connector - Install the I/O cable connector, aligning the pins.



Data I/O Connector (standard)

Pin	Signal
1	Common
2	Data receive
3	Data transmit
4	Auxiliary power in

2. Connect the I/O cable connector to your computer's serial port.

Test

Note:
See SEATERM's Help files.

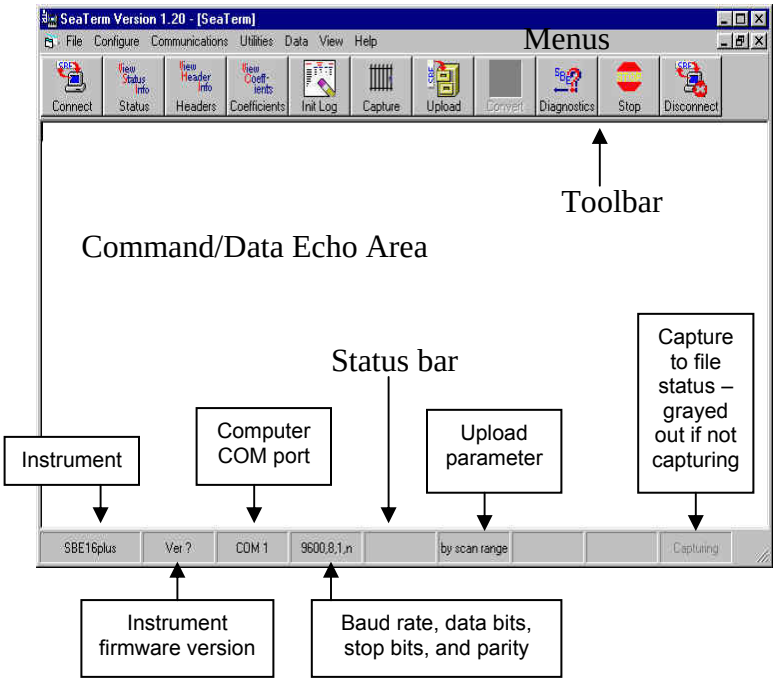
Proceed as follows:

1. Double click on SeaTerm.exe. If this is the first time the program is used, the setup dialog box may appear:

SeaTerm Setup
The initialization file: SeaTerm.ini was not found in the Windows directory. Please enter the following setup information.
**IMPORTANT: To complete setup, review the configuration setting for your instrument by selecting your instrument type from the Configure menu list.
Instrument Type
SBE16plus
COM Port
1
OK

   Select the instrument type (*SBE 16plus*) and the computer COM port for communication with the 16*plus*. Click OK.

2. The main screen looks like this:


SeaTerm Version 1.20 - [SeaTerm]
File Configure Communications Utilities Data View Help
Menus
Connect Status Headers Coefficients Init Log Capture Upload Convert Diagnostics Stop Disconnect
Toolbar
Command/Data Echo Area
Status bar
Capture to file status – grayed out if not capturing
Instrument
Computer COM port
Upload parameter
SBE16plus Ver 2 COM 1 9600,8,1,n by scan range Capturing
Instrument firmware version
Baud rate, data bits, stop bits, and parity

- Menus – Contains tasks and frequently executed instrument commands.
- Toolbar – Contains buttons for frequently executed tasks and instrument commands. All tasks and commands accessed through the Toolbar are also available in the Menus. To display or hide the Toolbar, select View Toolbar in the View menu. Grayed out Toolbar buttons are not applicable.
- Command/Data Echo Area – Echoes a command executed using a Menu or Toolbar button, as well as the instrument's response. Additionally, a command can be manually typed in this area, from the available commands for the instrument. Note that the instrument must be *awake* for it to respond to a command (use Connect on the Toolbar to wake up the instrument).
- Status bar – Provides status information. To display or hide the Status bar, select View Status bar in the View menu.

Note:
There is at least one way, and as many as three ways, to enter a command:
- Manually type a command in Command/Data Echo Area
- Use a menu to automatically generate a command
- Use a Toolbar button to automatically generate a command

Note:
Once the system is configured and connected (Steps 3 through 5 below), to update the Status bar:
- on the Toolbar, click Status; or
- from the Utilities menu, select Instrument Status.

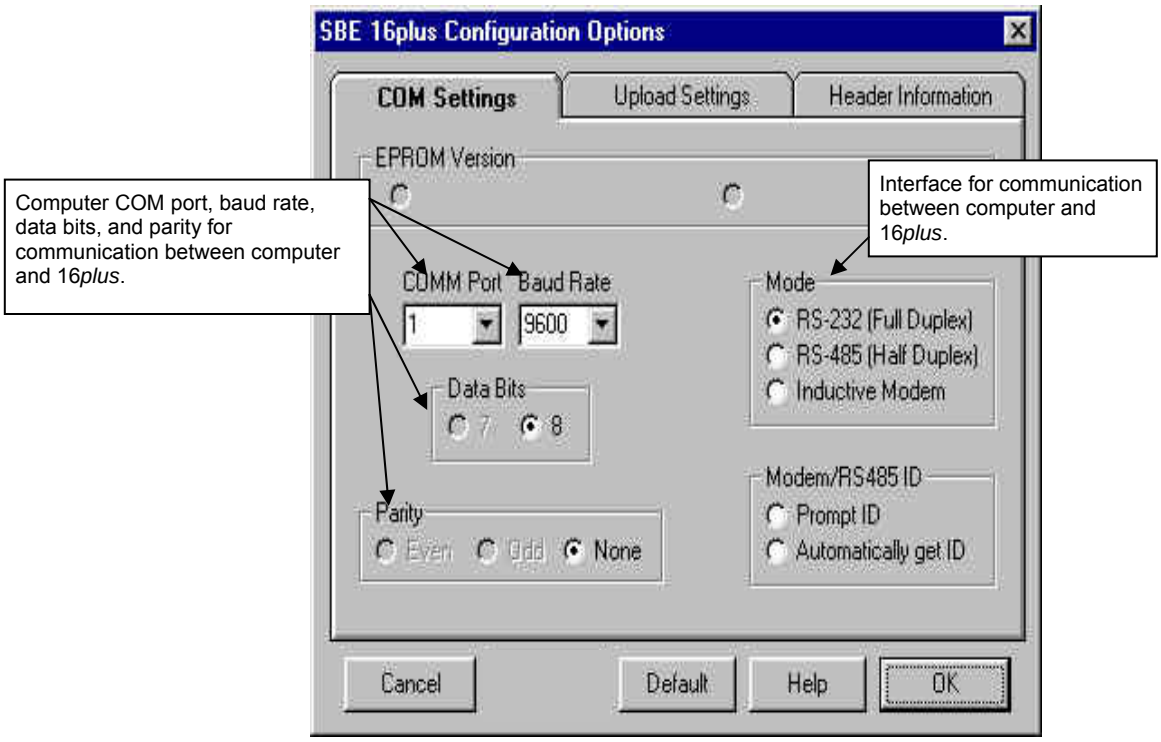
SEATERM sends the status command, which displays in the Command/Data Echo Area, and updates the Status bar.

Following are the Toolbar buttons applicable to the SBE 16*plus*:

Toolbar Buttons	Description	Equivalent Command*
Connect	Re-establish communications with 16*plus*. Computer responds with S> prompt. 16*plus goes to sleep* after 2 minutes without communication from computer have elapsed.	(press Enter key)
Status	Display instrument setup and status (logging, samples in memory, etc.).	**DS**
Headers	View data headers (header number, date and time, first and last sample, and sample interval). A new header is generated at start of sampling and every subsequent 1000 scans.	**DH**
Coefficients	Display calibration coefficients.	**DCal**
Init Log	Reset data pointers and header numbers. This should be performed **after existing data has been uploaded from 16*plus*** and prior to recording new data.	**InitLogging**
Capture	Capture instrument responses on screen to file; may be useful for diagnostics. File has .cap extension. Press Capture again to turn off capture. Capture status displays in Status bar.	**—**
Upload	Upload data stored in memory, in format Sea-Bird's data processing software can use (raw hex). Uploaded data has .hex extension. Before using Upload: • Configure upload and header parameters in Configure menu • **Stop logging** by sending **Stop**.	**DDb,e** (use Upload button if you will be processing data with SBE Data Processing)
Diagnostics	Perform one or more diagnostic tests on 16*plus*. Diagnostic test(s) accessed in this manner are non-destructive – they do not write over any existing instrument settings.	**DS, DCal, TS, and TSR**
Stop	Interrupt and end current activity, such as uploading or diagnostic test.	(press Esc key or Ctrl C)
Disconnect	Free computer COM port used to communicate with 16*plus*. COM port can then be used by another program.	**—**

*See *Command Descriptions* in *Section 4: Deploying and Operating SBE 16plus*.

3. In the Configure menu, select *SBE 16plus*. The dialog box looks like this:



Make the selections in the Configuration Options dialog box:
- **COMM Port**: COM 1 through COM 10, as applicable
- **Baud Rate**: 9600 (documented on instrument Configuration Sheet)
- **Data Bits**: 8
- **Parity**: None
- **Mode**: RS-232 (Full Duplex)

Click OK to save the settings.

Notes:
- SEATERM's baud rate must be the same as the 16*plus* baud rate (set with **Baud=**). Baud is factory-set to 9600, but can be changed by the user (see *Command Descriptions* in *Section 4: Deploying and Operating SBE 16plus*).
- When you click OK, SEATERM saves the Configuration Options settings to the SeaTerm.ini file in your Windows directory. SeaTerm.ini contains the last saved settings for **each** instrument. When you open SEATERM and select the desired instrument (SBE 16*plus*, 37, 39, etc.) in the Configure menu, the Configuration Options dialog box shows the last saved settings for that instrument.

4. In the Communications menu, select *Options / Cycle baud when connecting*.

5. Click Connect on the Toolbar. SEATERM tries to connect to the 16*plus* at the baud set in Step 3. If it cannot, it cycles through all other possible baud rates to try to connect. When it connects, the display looks like this:

   S>

   This shows that correct communications between the computer and 16*plus* has been established.
   If the system does not respond with the S> prompt:
   - Click Connect again.
   - Verify the correct instrument was selected in the Configure menu and the settings were entered correctly in the Configuration Options dialog box. Note that the baud rate is documented on the instrument Configuration Sheet.
   - Check cabling between the computer and 16*plus*.

Notes:
- The 16*plus* automatically enters quiescent (sleep) state after 2 minutes without receiving a command. This timeout algorithm is designed to conserve battery energy if the user does not send **QS** to put the 16*plus* to sleep. If the system does not appear to respond, click Connect on the Toolbar to reestablish communications.
- Sending the status command causes the optional pump to turn on for a moment, so that the 16*plus* can measure and output the pump current. Because the pump is designed to be water lubricated, you may hear a noise when the impeller spins in air. Running the pump *dry* for **short** periods (for example, when sending the status command) will not harm the pump.

6. Display 16*plus* status information by clicking Status on the Toolbar or typing **DS** and pressing the Enter key. The display looks like this:

```
SBE 16plus V 1.8c SERIAL NO. 4300 03 Jul 2007 14:11:48
vbatt = 10.3, vlith = 8.5, ioper = 62.5 ma, ipump = 21.6 ma,
iserial = 48.2 ma
status = not logging
sample interval = 15 seconds, number of measurements per sample = 2
samples = 823, free = 465210
run pump during sample, delay before sampling = 2.0 seconds
transmit real-time = yes
battery cutoff = 7.5 volts
pressure sensor = strain gauge, range = 1000.0
SBE 38 = no, SBE 50 = yes, Gas Tension Device = no
Ext Volt 0 = no, Ext Volt 1 = no, Ext Volt 2 = no, Ext Volt 3 = no
echo commands = yes
output format = raw HEX
serial sync mode disabled
```

7. Command the 16*plus* to take a sample by typing **TS** and pressing the Enter key. The display looks like this (if 16*plus* includes optional internally mounted pressure sensor, and is set up for converted decimal output format, no output salinity or sound velocity, and no auxiliary sensors):

   ```
   23.7658,0.00019, 0.062, 03 Jul 2007, 14:11:60
   ```

   where 23.7658 = temperature in degrees Celsius
   0.00019 = conductivity in S/m
   0.062 = pressure in db
   03 Jul 2007 = date
   08:49:10 = time

   These numbers should be reasonable; i.e., room temperature, zero conductivity, barometric pressure (gauge pressure), current date and time (set at factory to Pacific Daylight or Standard Time).

8. Command the 16*plus* to go to sleep (quiescent state) by typing **QS** and pressing the Enter key.

The SBE 16*plus* is ready for programming and deployment.

Section 4: Deploying and Operating SBE 16*plus*

This section includes discussions of:

- Sampling modes, including example sets of commands
- Pump operation
- Real-time setup
- Timeout description
- Command descriptions
- Data output formats
- Deployment
- Acquiring real-time data with SEASAVE
- Recovery - physical handling and uploading data
- Processing data

Note:
Separate software manuals and Help files contain detailed information on installation, setup, and use of Sea-Bird's software.

Sampling Modes

The SBE 16*plus* has three basic sampling modes for obtaining data:
- Polled Sampling
- Autonomous Sampling
- Serial Line Synchronization

Commands can be used in various combinations to provide a high degree of operating flexibility.

Note:
The 16*plus* automatically enters quiescent state after 2 minutes without receiving a command.

Descriptions and examples of the sampling modes follow. Note that the SBE 16*plus* response to each command is not shown in the examples. Review the operation of the basic sampling modes and the commands described in *Command Descriptions* before setting up your system.

Polled Sampling

On command, the SBE 16*plus* takes one sample of data and sends the data to the computer. Storing of data in the 16*plus* FLASH memory is dependent on the particular command used.

Example: ***Polled Sampling*** (user input in bold)
Wake up 16*plus*. Set date and time to September 1, 2004 at 9 am. Set up with internally mounted strain gauge pressure sensor and 1 voltage sensor, no pump, take and average 4 measurements for each sample, and output data in converted decimal format. After all parameters are entered, verify setup. Command 16*plus* to take a sample, and send data to computer (do not store data in 16*plus* memory). Send power-off command.

(Click Connect on Toolbar to wake up.)
S>**MMDDYY=090104**
S>**HHMMSS=090000**
S>**PTYPE=1**
S>**VOLT0=Y**
S>**PUMPMODE=0**
S>**NCYCLES=4**
S>**OUTPUTFORMAT=3**
S>**DS** (to verify setup)
S>**TS**
S>**QS**

Autonomous Sampling (logging)

Note:
Set **OutputFormat=0** if you will be using Sea-Bird's real-time data acquisition software (SEASAVE).

At pre-programmed intervals, the SBE 16*plus* wakes up, samples data, stores the data in its FLASH memory, and enters quiescent (sleep) state. The 16*plus* goes to sleep for a minimum of 3 seconds between each sample. Logging is started with **StartNow** or **StartLater**, and is stopped with **Stop**. If real-time data is to be transmitted (**TxRealTime=Y**), data is transmitted after measurements are complete for that sample and before sampling begins for the next sample.

Example: ***Autonomous Sampling*** (user input in bold)

Wake up 16*plus*. Set date and time to September 1, 2004 at 9 am. Initialize logging to overwrite previous data in memory. Set up with internally mounted strain gauge pressure sensor and 1 voltage sensor, take a sample every 120 seconds, take and average 4 measurements for each sample, do not transmit real-time data, and output data in raw hex format. Set up pump to run for 0.5 seconds before each sample. Set up to start logging on September 15, 2004 at 11 am. Send command to start logging at designated date and time. After all parameters are entered, verify setup. Send power-off command.

(Click Connect on Toolbar to wake up.)

S>**MMDDYY=090104**
S>**HHMMSS=090000**
S>**INITLOGGING**
S>**PTYPE=1**
S>**VOLT0=Y**
S>**SAMPLEINTERVAL=120**
S>**NCYCLES=4**
S>**TXREALTIME=N**
S>**OUTPUTFORMAT=0**
S>**PUMPMODE=1**
S>**STARTMMDDYY=091504**
S>**STARTHHMMSS=110000**
S>**STARTLATER**
S>**DS** (to verify setup)
S>**QS**

Deploy 16*plus*. Logging starts automatically at designated date and time.

Upon recovering 16*plus*, stop logging. Upload data in memory, in format SBE Data Processing can use. Send power-off command.

(Click Connect on Toolbar to wake up.)

S>**STOP**

(Click Upload on Toolbar – program leads you through screens to define data to be uploaded and where to store it.)

S>**QS**

Serial Line Synchronization (Serial Line Sync)

Serial Line Sync allows a simple pulse on the RS-232 line to initiate a sample. This mode provides easy integration with ADCPs or current meters, which can synchronize SBE 16*plus* sampling with their own without drawing on their battery or memory resources.

If this mode is enabled (**SyncMode=Y**) and the SBE 16*plus* is powered down, setting the RS-232 RX line high (3 –10 VDC) for 1 to 1000 milliseconds wakes up the SBE 16*plus* and executes a Take Sample command:

- Take sample
- Store sample in FLASH memory
- Output real-time data (if **TxRealTime=Y**)

After executing the Take Sample command, the SBE 16*plus* checks the RS-232 line and **SyncWait**. These determine whether to power down immediately or accept commands from the computer, and whether to leave the serial line sync mode enabled or disable it:

- **SyncWait=0** and **Mark State** (RS-232 RX line less than 0.5 volts) SBE 16*plus* immediately powers down. Serial line sync mode remains enabled (**SyncMode=Y**).
- **SyncWait=0** and **Space State** (RS-232 RX line greater than 3 volts) SBE 16*plus* monitors the RS-232 line for a time equivalent to 25 characters (actual length of time is dependent on the baud rate):
  - Line remains in space state - SBE 16*plus* disables serial line sync mode (sets **SyncMode=N**) at end of time. Once serial line sync mode is disabled, you can communicate with the SBE 16*plus* using the full range of commands (operating commands, logging commands, uploading command, etc.).
  - Line returns to mark state - SBE 16*plus* immediately powers down. Serial line sync mode remains enabled (**SyncMode=Y**).
- **SyncWait>0**
  SBE 16*plus* monitors the RS-232 line for **SyncWait** seconds. Each time a carriage return (Enter key) is detected, the time-out clock is reset to 2 minutes. Within that time period, you can communicate with the SBE 16*plus* using the full range of commands (operating commands, logging commands, uploading command, etc.). While the SBE 16*plus* is monitoring:
  - More than 25 break characters are received - SBE 16*plus* disables serial line sync mode (sets **SyncMode=N**). Once serial line sync mode is disabled, you can communicate with the SBE 16*plus* using the full range of commands (operating commands, logging commands, uploading command, etc.).
  - Less than 25 break characters are received - SBE 16*plus* powers down when the time-out clock runs down. Serial line sync mode remains enabled (**SyncMode=Y**).

In summary, to disable serial line sync mode after executing the take sample command:

- **SyncWait** = 0
  Put RS-232 line in space state (greater then 3 volts) for time equivalent to 25 characters.
- **SyncWait** > 0
  - Send 25 break characters, or
  - If **SyncWait** is greater than 5 seconds, send **SyncMode=N** after waiting at least 3 seconds after executing the take sample command.

Note:
If running **SEATERM**, select *Send 5 second break* in the Communications menu to hold the RS-232 RX line in space state for 5 seconds. This will always be more than 25 break characters, and will cause the 16*plus* to exit serial line sync mode.

Example: ***Serial Line Sync*** (user input in bold)
Wake up 16*plus*. Set current date and time to September 1, 2004 at 9 am. Initialize logging to overwrite previous data in memory. Set up with internally mounted strain gauge pressure sensor and 1 voltage sensor, take and average 4 measurements for each sample, output data in converted decimal format. Set **SyncWait** to 25 seconds and enable serial line sync mode. After all parameters are entered, verify setup. Send power off command.

(Click Connect on Toolbar to wake up.)
S>**MMDDYY=090104**
S>**HHMMSS=090000**
S>**INITLOGGING**
S>**PTYPE=1**
S>**VOLT0=Y**
S>**NCYCLES=4**
s>**TXREALTIME=Y**
S**>OUTPUTFORMAT=3**
S>**SYNCWAIT=25**
S>**SYNCMODE=Y**
S>**DS** (to verify setup)
S>**QS**

Take samples using serial line sync mode:

(Set RS-232 RX line high [3-10 VDC] for 1-1000 milliseconds. 16*plus* takes sample, stores data in memory, and outputs data. Do not send any characters – 16*plus* powers down after 25 seconds.)
(Repeat this process at periodic intervals as desired.)

When ready to upload all data to computer, disable serial line sync mode, and then upload data and power down:

(Set RS-232 RX line high [3-10 VDC] for 1-1000 milliseconds. 16*plus* takes sample, stores data in memory, and outputs data.)
(Within 25 seconds [**SyncWait** timeout], select *Send 5 second break* in Communications menu to disable serial line sync mode.)
(Press Enter key to get **S>** prompt.)
S>**DS** (to verify 16*plus* is communicating)
(Click Upload on Toolbar – program leads you through screens to define data to be uploaded and where to store it.)
S>**QS**

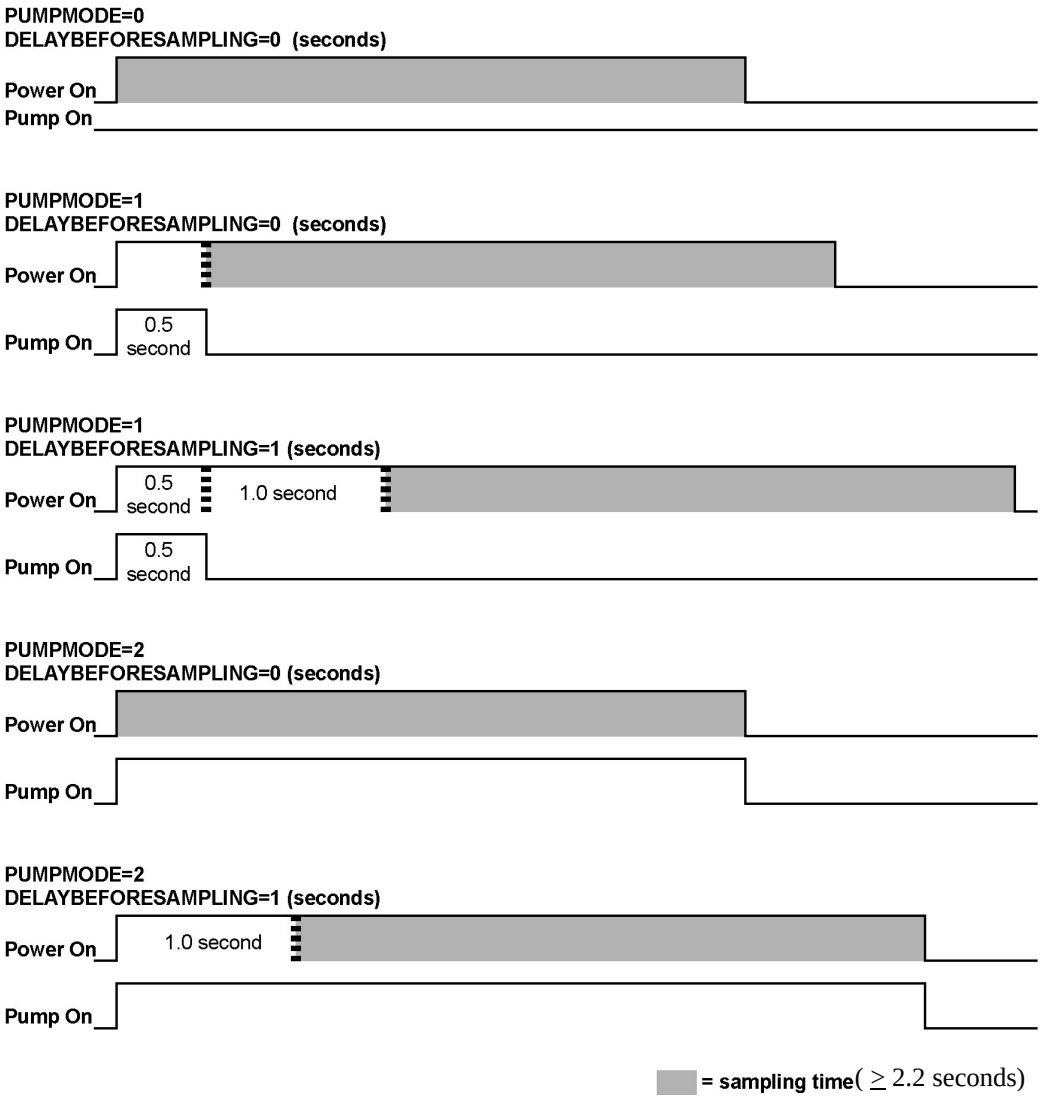
Pump Operation

Do not run the pump dry. The pump is water lubricated; running it without water will damage it. If briefly testing your system in dry conditions, fill the inside of the pump head with water via the pump exhaust port. This will provide enough lubrication to prevent pump damage during brief testing.

Pump operation is governed by two user-programmable parameters:

- **PumpMode=0**, **1**, or **2**
  The 16*plus* can be set up to operate with no pump (0), with the pump running for 0.5 seconds before each sample (1), or with the pump running during each sample (2).
- **DelayBeforeSampling=**
  The 16*plus* can be set up to delay sampling after turning on external voltage sensors. Some instruments require time to equilibrate or stabilize after power is applied, to provide good quality data.

PumpMode= and **DelayBeforeSampling=** interact in the operation of the pump, as shown below. Recommendations for settings are provided on the next page.



Note:
Sampling time includes time for instrument to warm up as well as time to actually measure parameters. The 2.2 second sampling time is for 16*plus* with no internally mounted pressure sensor, and 1 measurement / sample (**NCycles=1**). See *Specifications* in *Section 2: Description of SBE 16plus* for sampling times for other setups.

Pump Setting Recommendations

Sea-Bird provides the following recommendations for pump settings. Note that longer pump times increase power usage, reducing battery endurance. See *Battery Endurance* in *Section 2: Description of SBE 16plus* for sample battery endurance calculations.

Pump through Conductivity Cell Only (SBE 5M, 5P, or 5T pump)

For most deployments, set **PumpMode=1** and **DelayBeforeSampling=0**. The pump operates for 0.5 seconds before the conductivity measurement is made, providing enough time to ventilate the cell and bring in a new sample of water.

If the 16*plus* is moored in an area with large thermal gradients, it may be necessary to pump for a longer period of time, to eliminate any cell thermal mass effects on the measurement. In this case, set **PumpMode=2** and set **DelayBeforeSampling=** to a non-zero value, providing additional ventilation time (allowing the conductivity cell temperature to equilibrate to the water temperature) before taking the measurement.

Pump through Conductivity Cell and SBE 43 Dissolved Oxygen Sensor (requires SBE 5P or 5T pump)

Set **PumpMode=2**.

As the pump brings new water into the SBE 43 plenum, some time is required for the sensor to equilibrate to the new oxygen level. The time required is dependent on the sensor's membrane thickness, and on the water temperature. Prior to 2007, all SBE 43s were sold with a 0.5 mil thick membrane. Beginning in 2007, Sea-Bird began offering two membrane thicknesses – 0.5 mil (faster response, typically for profiling applications) and 1.0 mil (slower response but more durable, typically for moored applications).

- For a **0.5 mil thick** membrane – Recommended **DelayBeforeSampling=** varies in a non-linear fashion, from 15 seconds at 15 °C to 30 seconds at 0 °C.
- For a **1.0 mil thick** membrane – Recommended **DelayBeforeSampling=** varies in a non-linear fashion, from 25 seconds at 15 °C to 40 seconds at 0 °C.

Note:
See *Application Note 64: SBE 43 Dissolved Oxygen Sensor – Background Information, Deployment Recommendations, and Cleaning and Storage* for the response time curves.

Pump through Conductivity Cell and Beckman- or YSI-type Dissolved Oxygen Sensor (requires SBE 5P or 5T pump)

Set **PumpMode=2**. Set **DelayBeforeSampling=** to 120 to 180 seconds, allowing time for the oxygen sensor to polarize before taking the measurement.

Real-Time Setup

Notes:
- Set baud rate with **Baud=**.
- Set data storage rate and real-time output rate with **SampleInterval=**.
- Include auxiliary sensors in the data stream with **VoltN=** commands.
- Set output format with **OutputFormat=**.
- Set **TxRealTime=Y** to output real-time data.
- If using external power, see *External Power* in *Section 2: Description of SBE 16plus* for power limitations on cable length.

Baud Rate and Cable Length

The rate that real-time data can be transmitted from the SBE 16*plus* is dependent on the amount of data to be transmitted per scan and the serial data baud rate:

Time required to transmit data =
(number of characters * 10 bits/character) / baud rate

where

Number of characters is dependent on the included data and output format (see *Data Output Formats*).
Add 2 to the number of characters shown in the output format, to account for the carriage return and line feed at the end of each scan.
For decimal output (**OutputFormat=2**, **3**, **4**, or **5**), include decimal points, commas, and spaces when counting the number of characters.

Time required to transmit data plus the time required to make the measurements must be less than the (interval between samples – 3 seconds) for Autonomous Sampling, because the 16*plus* goes to sleep for a minimum of 3 seconds between each sample.

The length of cable that the SBE 16*plus* can drive is also dependent on the baud rate. The allowable combinations are:

Maximum Cable Length (meters)	Maximum Baud Rate
1600	600
800	1200
400	2400
200	4800
100	9600
50	19200
25	38400

Example 1 - 16*plus* with optional internally mounted strain gauge pressure sensor, configured with 4 external voltages and 10 measurements/sample (**NCycles=10**). What is the smallest sample interval you can use if you want to transmit real-time data over 800 m with **OutputFormat=0** (raw hexadecimal data)?

With 800 meters of cable, the 16*plus* requires a baud rate of 1200 or less.
Number of characters for **OutputFormat=0** (from *Data Output Formats*) =
6 (T) + 6 (C) + 6 (P) + 4 (P temperature compensation) + 4*4 (external voltages) + 8 (time) + 2 (carriage return & line feed) = 48
Time required to transmit data = (48 characters * 10 bits/character) / 1200 = 0.4 seconds

Minimum time required for each sample =
(2.2 + 0.3) second sampling time + [(10-1) * 0.25 seconds] + 0.4 seconds to transmit real-time
+ 3 seconds to go to sleep between samples = 8.15 seconds < minimum allowable sample interval of 10 seconds
Therefore, set **SampleInterval=10**, storing and transmitting one sample every 10 seconds for this configuration.

Example 2 – Same as above, but you have set **DelayBeforeSampling=15**.
Minimum time required for each sample = 8.15 seconds + 15 seconds (delay after turning on power) =
23.15 seconds, round up to 24 seconds
Therefore, set **SampleInterval=24**, storing and transmitting one sample every 24 seconds.

Real-Time Data Acquisition

Real-time data can be acquired in either of the following ways:

- With SEASAVE (**typical method**) – When the SBE 16*plus* is set up for autonomous sampling, data can be viewed in SEASAVE in tabular form or as plots, as raw data or as converted (engineering units) data. Data acquired with SEASAVE can be processed with SBE Data Processing. See SEASAVE's Help files for details on setting up the program displays, baud rates, etc., and beginning data acquisition.

- With SEATERM – Click Capture on SEATERM's Toolbar. Begin sampling. The data displayed in SEATERM will be saved to the designated file. Process the data as desired. Note that this file **cannot be processed by SEASAVE or SBE Data Processing, as it does not have the required headers and format for Sea-Bird's processing software**.

Note:
If the FLASH memory is filled to capacity, data sampling and transmission of real-time data (if programmed) continue, but excess data is not saved in memory.

Timeout Description

The SBE 16*plus* has a timeout algorithm. If the 16*plus* does not receive a command or sample data for 2 minutes, it powers down its main digital circuits. This places the 16*plus* in quiescent state, drawing minimal current. **To re-establish control (wake up), click Connect on the Toolbar or press the Enter key.** The system responds with the S> prompt.

Command Descriptions

This section describes commands and provides sample outputs.
See *Appendix III: Command Summary* for a summarized command list.

When entering commands:

- Input commands to the 16*plus* in upper or lower case letters and register commands by pressing the Enter key.
- The 16*plus* sends `? CMD` if an invalid command is entered.
- If the system does not return an `S>` prompt after executing a command, press the Enter key to get the `S>` prompt.
- If a new command is not received within 2 minutes after the completion of a command, the 16*plus* returns to the quiescent (sleep) state.
- If in quiescent state, re-establish communications by clicking Connect on the Toolbar or pressing the Enter key to get an `S>` prompt.
- If the 16*plus* is transmitting data and you want to stop it, press the Esc key or click Stop on the Toolbar (or type ^C). Press the Enter key to get the `S>` prompt.
- The 16*plus* cannot have samples with different scan lengths (more or fewer data fields per sample) in memory. If the scan length is changed by commanding it to add or subtract a data field (such as an external voltage), the 16*plus* must initialize logging. Initializing logging sets the sample number and header number to 0, so the entire memory is available for recording data with the new scan length. **Initializing logging should only be performed after all previous data has been uploaded**. Therefore, commands that change the scan length (**PType=**, **Volt0=**, **Volt1=**, **Volt2=**, **Volt3=**, **SBE38=**, **SBE50=**, **GTD=**, and **DualGTD=**) prompt the user for verification before executing, to prevent accidental overwriting of existing data.
- The 16*plus* responds only to **DS**, **DCal**, **TS**, **SL**, **SLT**, **QS**, and **Stop** while sampling autonomously. If you wake the 16*plus* while it is sampling autonomously (for example, to send **DS** to check on progress), it will temporarily stop sampling. Autonomous sampling resumes when it goes back to sleep again (either by sending **QS** or after the 2-minute timeout).
- The 16*plus* responds only to **DS**, **DCal**, **TS**, **SL**, **SLT**, **QS**, and **Stop** while *waiting to start autonomous sampling* (if you sent **StartLater** but sampling has not started yet). To send any other commands, send **Stop**, send the desired commands to modify the setup, and then send **StartLater** again.

Entries made with the commands are permanently stored in the SBE 16*plus* and remain in effect until you change them.

- The only exception occurs if the electronics are removed from the housing and disconnected from the battery Molex connector (see *Appendix II: Electronics Disassembly/Reassembly*). Upon reassembly, reset the date and time (**MMDDYY=** and **HHMMSS=**) and initialize logging (**InitLogging**).

Notes:
- If the battery voltage is below the cut-off (7.5 volts), the following displays in response to **DS**: `WARNING: LOW BATTERY VOLTAGE!!` Replace the batteries before continuing.
- If configured with a pump, sending **DS** causes the pump to turn on for a moment, so that the 16*plus* can measure and output the pump current. Because the pump is designed to be water lubricated, you will hear a noise when the impeller spins in air. Running the pump *dry* for such a **short** time will not harm the pump.
- In the example below, no voltage channels are enabled, so external voltage currents (`iext01=` and `iext23=`) are not shown.
- If the 16*plus* is set up with a WET Labs ECO-FL fluorometer with Bio-Wiper (**Biowiper=Y**), the **DS** reply shows: `wait 4 seconds for biowiper to close` before it measures the enabled external voltage currents.
- If the 16*plus* is set up for dual GTDs, the status command shows: `Dual Gas Tension Device = Yes`

Status Command

DS

Display operating status and setup. Equivalent to Status on Toolbar.

List below includes, where applicable, command used to modify parameter.
- Firmware version, serial number, date and time [**MMDDYY=** and **HHMMSS=**]
- Voltages and currents (main and back-up lithium battery voltages, operating and pump current, external voltage currents, and RS-232 sensor current)
- Logging status (not logging, logging, waiting to start at . . ., or unknown status)
- Sample interval [**SampleInterval=**] and number of measurements to take and average per sample [**NCycles=**]
- Integration time [**ParosIntegration=**] (only if pressure sensor = Digiquartz)
- Number of samples and available sample space in memory
- Pump turn-on parameter [**PumpMode=**] and turn-on delay [**DelayBeforeSampling=**]
- Transmit data real-time [**TxRealTime=**]?
- Battery cut-off voltage
- Internally mounted pressure sensor type [**PType=**] and range [**PRange=**]
- Sample SBE 38 secondary temperature sensor [**SBE38=**]? Sample SBE 50 pressure sensor [**SBE50=**]? Sample Gas Tension Device or Dual Gas Tension Devices [**GTD=** or **DualGTD=**]?
- Sample external voltages 0, 1, 2, and 3? [**Volt0=** through **Volt3=**]
- Show entered commands on screen as you type [**ECHO=**]?
- Output format [**OutputFormat=**]
- Output salinity [**OutputSal=**] and sound velocity [**OutputSV=**]? (only if output format = converted decimal)
- Serial sync mode state [**SyncMode=**] and wait time [**SyncWait=**] (only if serial sync mode enabled)
- Output sigma-t, voltage, and current with each sample [**OutputUCSD=**]? (only if output format = converted decimal; only appears in response if set to Y)

Example: (user input in bold)

```
S>DS
SBE 16plus V 1.8c SERIAL NO. 4300 03 Jul 2007 14:11:48                    [MMDDYY=, HHMMSS=]
vbatt = 10.3, vlith = 8.5, ioper = 62.5 ma, ipump = 21.6 ma,
iserial = 48.2 ma
status = not logging
sample interval = 15 seconds, number of measurements per sample = 2       [SampleInterval=, NCycles=]
samples = 823, free = 465210
run pump during sample, delay before sampling = 2.0 seconds   [PumpMode=, DelayBeforeSampling=]
transmit real-time = yes                                                  [TxRealTime=]
battery cutoff = 7.5 volts
pressure sensor = strain gauge, range = 1000.0                            [PType=,PRAange=]
SBE 38 = no, SBE 50 = yes, Gas Tension Device = no          [SBE38=, SBE50=, GTD=, DualGTD=]
Ext Volt 0 = no, Ext Volt 1 = no, Ext Volt 2 = no, Ext Volt 3 = no        [Volt0= through Volt3=]
echo commands = yes                                                       [Echo=]
output format = raw HEX                                                   [OutputFormat=]
serial sync mode disabled                                                 [SyncMode=]
```

General Setup Commands

Notes:
- **DDMMYY=** and **MMDDYY=** are equivalent. Either can be used to set the date.
- **Always set date and then time.** If a new date is entered but not a new time, the new date will not be saved. If a new time is entered without first entering a new date, the date will reset to the last date it was set for with **MMDDYY=** or **DDMMYY=**.

MMDDYY=mmddyy — Set real-time clock month, day, and year. Must be followed by **HHMMSS=** to set time.

DDMMYY=ddmmyy — Set real-time clock day, month, and year. Must be followed by **HHMMSS=** to set time.

HHMMSS=hhmmss — Set real-time clock hour, minute, and second.

Example: Set current date and time to 05 October 2007 12:00:00 (user input in bold).

S>**MMDDYY=100507**
S>**HHMMSS=120000**

or

S>**DDMMYY=051007**
S>**HHMMSS=120000**

Notes:
- The 16*plus* baud rate (set with **Baud=**) must be the same as SEATERM's baud rate (set in the Configure menu).
- An RS-232 sensor (SBE 38, SBE 50, or GTD) integrated with the 16*plus* must use the same baud rate as used by the 16*plus*. See the RS-232 sensor's manual to set its baud rate.

Baud=x — **x=** baud rate (600, 1200, 2400, 4800, 9600, 19200, or 38400). Default 9600.

Echo=x — **x=Y**: Echo characters received from computer (default) - computer monitor will show entered commands as you type.

x=N: Do not echo characters.

TxRealTime=x — Applies to both autonomous (logging) and serial line sync modes.
x=Y: Output real-time data.

x=N: Do not output real-time data.

Note:
Pump operation is affected by both **PumpMode=** and **DelayBeforeSampling=**. See *Pump Operation*.

PumpMode=x — **x=0**: No pump.

x=1: Run pump for 0.5 seconds before each sample (typical for pumping through conductivity cell only, with no auxiliary sensors connected to plumbing).

x=2: Run pump during each sample (typical for pumping through conductivity cell and in-line auxiliary sensor).

Note:
NCycles=, **ParosIntegration=** and **DelayBeforeSampling=** affect the time required to sample. If these are too high, the 16*plus* is unable to take the required number of measurements and do the calculations within **SampleInterval=**. When it is beginning to log, the 16*plus* checks all parameters, and if necessary it internally increases **SampleInterval=**.

NCycles=x — **x=** number of measurements to take and average for each sample (default = 1). 16*plus* takes and averages **NCycles=** measurements (each 0.25 seconds apart) for each sample; averaged data is stored in FLASH memory and (if **TxRealTime=Y**) transmitted real-time. Maximum **NCycles=** is *smaller* of 255 *or* [4 * (**SampleInterval** - 3)].

General Setup Commands (*continued*)

Notes:
- **InitLogging** and **SampleNumber=0** have identical effects. Use either command to initialize logging.
- Initializing logging sets sample and header number to 0 *internally*. However, for data output, the first sample number and header number is 1.
- **Do not initialize logging until all data has been uploaded.** These commands do not delete data; they reset the data pointer. **If you accidentally initialize logging before uploading**, recover data as follows:
  1. Set **SampleNumber=a** and **HeaderNumber=b**, where **a** and **b** are your estimate of number of samples and headers in memory.
  2. Upload data. If **a** is more than actual number of samples or **b** is more than actual number of headers in memory, data for non-existent samples/headers will be bad, random data. Review uploaded data file carefully and delete any bad data.
  3. If desired, increase **a** and/or **b** and upload data again, to see if there is additional valid data in memory.

InitLogging

Initialize logging - after all previous data has been uploaded, initialize logging before starting to sample again to make entire memory available for recording. This command sets sample number (**SampleNumber=**) and header number (**HeaderNumber=**) to 0 internally. If not set to 0, data will be stored after last recorded sample. **Do not send InitLogging until all existing data has been uploaded.**

SampleNumber=x

x= sample number for first sample when sampling begins. After all previous data has been uploaded, send **SampleNumber=0** (sets sample and header number to 0 internally) before starting to sample to make entire memory available for recording. If not set to 0, data will be stored after last recorded sample. **Do not send SampleNumber=0 until all existing data has been uploaded.**

HeaderNumber=x

x= header number for when sampling begins. Typically only used to recover data if you accidentally initialize logging (using **InitLogging** or **SampleNumber=0**) before uploading all existing data. Note that 16*plus* writes a new header each time autonomous sampling is started and / or after every
1000 samples are stored in memory.

FlashInit

Map bad blocks and erase FLASH memory, **destroying all data**. 16*plus* requires you to enter command twice, to provide verification before it proceeds. All data bits are set to 1. Sample number, header number, and data pointers are set to 0. Allow 15 minutes for process.

Send **FlashInit** (after uploading all data) if there are FLASH Read errors in Status (**DS**) response. If not encountering errors, **FlashInit** is optional, as 16*plus* writes over previously recorded information when **InitLogging** is used before beginning sampling. However, knowledge of initial memory contents (i.e., all 1's) can be useful cross-check when data is retrieved.

QS

Quit session and place 16*plus* in quiescent (sleep) state. Main power is turned off. Data logging and memory retention are not affected.

Output Format Commands

See *Data Output Formats* after the command descriptions for complete details on all the formats.

Note:
Output format does not affect how data is stored in FLASH memory. Sea-Bird's real-time data acquisition (SEASAVE) and data processing (SBE Data Processing) software require data in raw hexadecimal (**OutputFormat=0**).

Typical use of the output format command is:
- Before beginning logging:
  - **If you will use SEASAVE to view real-time data** - Set output format to raw hex.
  - **If you will use SEATERM to view real-time data** - Set output format to converted decimal for ease in viewing real-time data.
- After stopping sampling, use SEATERM's Upload button to upload data from memory. This automatically resets the format to raw hex (**OutputFormat=0**), so the data is compatible with SBE Data Processing.

OutputFormat=x

x=0: Output raw frequencies and voltages in hexadecimal; required for data that will be processed with Sea-Bird software. **Must use this format for acquiring and viewing real-time data in SEASAVE**. When using SEATERM's Upload button, SEATERM sends **OutputFormat=0**, causing 16*plus* to upload data from memory in raw hex, regardless of user-programmed **OutputFormat=**.

x=1: Output converted (engineering units) data in hexadecimal.

x=2: Output raw frequencies and voltages in decimal.

x=3: Output converted (engineering units) data in decimal; required to output salinity or sound velocity.

x=4: Output converted (engineering units) data in decimal, in XML.

x=5: Output converted (engineering units) data in decimal, in XML, modified formatting.

OutputSal=x

x=Y: Calculate and output salinity (psu). Only applies if **OutputFormat=3**, **4**, or **5**.

x=N: Do not calculate and output salinity.

OutputSV=x

x=Y: Calculate and output sound velocity (m/sec), using Chen and Millero formula (UNESCO Technical Papers in Marine Science #44). Only applies if **OutputFormat=3**, **4**, or **5**.

x=N: Do not calculate and output sound velocity.

OutputUCSD=x

x=Y: Calculate and output density sigma-t (kg/m^3), battery voltage, and operating current (mA) with data polled while logging. Voltage and current measured after delay before sampling, but before sampling. Only applies if **OutputFormat=3**, **4**, or **5**.

x=N: Do not.

Pressure Sensor Setup Commands

Notes:
- The 16*plus* requires verification when **PType=** is sent. 16*plus* responds: `this command will change the scan length and initialize logging. Proceed Y/N?` Press Y and the Enter key to proceed. The 16*plus* responds: `Scan length has changed, initializing logging`.
- The 16*plus* configuration (.con) file must match the **PType=** selection of internally mounted pressure sensor when viewing real-time data or processing uploaded data. View and edit the .con file in SEASAVE or SBE Data Processing. Note that **PType=** is factory-set to match the ordered instrument configuration.

PType=x

Internally mounted pressure sensor type.

x=0: No internally mounted pressure sensor.

x=1: Strain gauge.

x=3: Quartz with temperature compensation.

RefPress=x

x= reference pressure (gauge) in decibars to use if 16*plus* does not include an internally mounted pressure sensor. 16*plus* uses reference pressure in conductivity and salinity calculation. Value entered for **RefPress=** is displayed in calibration coefficient (**DCal**) command response if 16*plus* does not include internally mounted pressure sensor. Entry ignored if 16*plus* includes internally mounted pressure sensor. Note that if 16*plus* interfaces with an SBE 50 pressure sensor, it does not use SBE 50 data in conductivity and salinity calculation.

Notes:
- The 16*plus* does the integration for the Quartz pressure sensor *after* **NCycles=** measurements have been taken.
- **NCycles=**, **ParosIntegration=**, **DelayBeforeSampling=**, and **PumpMode=** affect the time required to sample. The 16*plus* checks these parameters when beginning to log, and if necessary it internally increases **SampleInterval=** to provide enough time to take the required number of measurements and do the calculations within **SampleInterval=**.

ParosIntegration=x

x= integration time for optional internally mounted Quartz pressure sensor (not applicable for strain gauge pressure sensor). Range 1 – 600 seconds; default 1 second. Increasing integration time increases resolution.
See *Specifications* in *Section 2: Description of SBE 16plus* for determining resolution for a Quartz pressure sensor.

Voltage Sensor Setup Commands

Notes:
- The 16*plus* configuration (.con) file must match this selection of number of external voltages when viewing real-time data or processing uploaded data. View and edit the .con file in SEASAVE or SBE Data Processing. Note that these parameters are factory-set to match the ordered instrument configuration.
- External voltage numbers 0, 1, 2, and 3 correspond to wiring of sensors to a voltage channel on the 16*plus* end cap (see *Dimensions and End Cap Connectors* in *Section 2: Description of SBE 16plus*). However, in the .con file, voltage 0 is the first external voltage in the data stream, voltage 1 is the second, etc.
- The 16*plus* requires verification when **Volt0 =** through **Volt3=** are sent. The 16*plus* responds: `this command will change the scan length and initialize logging. Proceed Y/N?` Press Y and the Enter key to proceed. The 16*plus* responds: `Scan length has changed, initializing logging.`

Volt0=x

x=Y: Enable external voltage 0.

x=N: Do not enable external voltage 0.

Volt1=x

x=Y: Enable external voltage 1.

x=N: Do not enable external voltage 1.

Volt2=x

x=Y: Enable external voltage 2.

x=N: Do not enable external voltage 2.

Volt3=x

x=Y: Enable external voltage 3. **Volt3=Y** is required if PAR sensor connected to optional PAR connector on 16*plus*.

x=N: Do not enable external voltage 3.

Example: Enable voltage sensors wired to channels 0 and 3 on end cap (user input in bold).

S>**VOLT0=Y**
S>**VOLT1=N**
S>**VOLT2=N**
S>**VOLT3=Y**

There will be 2 external sensor voltages in data stream. In .con file (in SBE Data Processing or SEASAVE), indicate *2* external voltage channels. Voltage 0 corresponds to sensor wired to external voltage channel 0; voltage 1 corresponds to sensor wired to external voltage channel 3.

Notes:
- If **DelayBeforeSampling** is too high, the 16*plus* will not be able to take **NCycles** samples within **SampleInterval** seconds; the 16*plus* internally increases **SampleInterval** to the smallest feasible number.
- Pump operation is affected by both **PumpMode=** and **DelayBeforeSampling=**. See *Pump Operation*.

DelayBeforeSampling=x

x= time (seconds) to wait after switching on external voltage before sampling (0-32,000 seconds). Default 0 seconds. Typical values if using:

- SBE 43 oxygen sensor – dependent on membrane thickness and on water temperature. Use with **PumpMode=2**. See *Pump Operation*.

- Beckman- or YSI-type oxygen sensor – 120 to 180 seconds is required to provide time for sensor to polarize. Use with **PumpMode=2**. See *Pump Operation*.

- Sea Tech fluorometer - 15 seconds is required to provide time for sensor to stabilize.

Note:
If an ECO-FL with Bio-Wiper is installed and **Biowiper=N**, sending **DS** will open the Bio-Wiper, but not provide enough powered time to close it again. If you then deploy the instrument with the Bio-Wiper open and with a delayed start time, the ECO-FL may become fouled because the Bio-Wiper will remain open until the first sample is completed.

Biowiper=x

x=Y: Configuration includes WET Labs ECO-FL fluorometer with Bio-Wiper. With this setup, 16*plus* is powered longer for **DS** command, providing sufficient time for Bio-Wiper to open and then shut again if Bio-Wiper is set up to take 1 measurement for each sample (see *Application Note 72* for details).

x=N (default): Configuration does not include ECO-FL with Bio-Wiper.

Notes:
- The 16*plus* configuration (.con) file must match this selection of RS-232 sensor when viewing real-time data or processing uploaded data. View and edit the .con file in SEASAVE or SBE Data Processing. Note that these parameters are factory-set to match the ordered instrument configuration.
- The 16*plus* requires verification when **SBE38=**, **SBE50=**, **GTD=**, or **DualGTD=** are sent. 16*plus* responds: `this command will change the scan length and initialize logging. Proceed Y/N?` Press Y and the Enter key to proceed. The 16*plus* responds: `Scan length has changed, initializing logging`.
- See the SBE 38, SBE 50, or Pro-Oceanus GTD manual for command details for these instruments.

RS-232 Sensor Setup Commands

If the 16*plus* is equipped with the optional 4-pin RS-232 bulkhead connector, it can interface with an SBE 38 secondary temperature sensor, an SBE 50 pressure sensor, or up to 2 Pro-Oceanus Gas Tension Devices (GTDs).

Setup for SBE 38:

Set up SBE 38 to interface with SBE 16*plus*, **before** you connect it to 16*plus*. Connect SBE 38 directly to computer, power with an external power supply, and (using SEATERM) set:
- **Baud rate** to same baud rate as 16*plus* (**Baud=**)
- **Interface** to RS-232 (**Interface=232**)
- **Sampling** to begin when power applied (**AutoRun=Y**)
- **Output** to converted data (**Format=C**)

Connect SBE 38 to SBE 16*plus* RS-232 bulkhead connector, using provided cable. In the 16*plus*, set **SBE38=Y** to enable interface.

SBE38=x

x=Y: Enable RS-232 SBE 38 secondary temperature sensor.

x=N: Do not enable SBE 38.

Setup for SBE 50:

Set up SBE 50 to interface with SBE 16*plus*, **before** you connect it to 16*plus*. Connect SBE 50 directly to computer, power with an external power supply, and (using SEATERM) set:
- **Baud rate** to same baud rate as 16*plus* (**Baud=**).
- **Output** to converted data in psia, decibars, meters, or feet (**OutputFormat= 1**, **2**, **3**, **4**, **5**, or **6**).

Connect SBE 50 to SBE 16*plus* RS-232 bulkhead connector, using provided cable. In the 16*plus*, set **SBE50=Y** to enable interface.

SBE50=x

x=Y: Enable RS-232 SBE 50 pressure sensor.

x=N: Do not enable SBE 50.

RS-232 Sensor Setup Commands (*continued*)

Note:
The 16*plus* sample interval (**SampleInterval=**) must be greater than or equal to the sum of the times required to sample. Total time is affected by the following:
- **Programmable pressure integration time for GTD**.
- **Programmable temperature integration time for GTD**.
- Minimum time required for 16*plus* to take a sample (≈ 2.5 sec).
- Time required for integration of optional Quartz pressure sensor (**ParosIntegration=**).
- Time required for 16*plus* to take and average **NCycles=** samples; samples are taken 0.25 sec apart.
- Delay after providing power to external voltage sensors before sampling (**DelayBeforeSampling=**).
- Time required to run pump before sampling (0.5 sec if **PumpMode=1**).

Setup for GTD:

Set up GTD to interface with SBE 16*plus*, **before** you connect it to 16*plus*. Connect GTD directly to computer, power with an external power supply, and (using software provided by Pro-Oceanus) set:
- **Baud rate** to same baud rate as 16*plus*.
- **Output** to millibars.
- Sum of **pressure integration time** and **temperature integration time** so that the GTD responds to a *take pressure reading* command in 40 seconds or less (required so that 16*plus* does not *time out* while waiting for a reply).

Connect GTD to SBE 16*plus* RS-232 bulkhead connector, using provided cable (end labeled *Pro-Oceanus* to GTD and end labeled *Sea-Bird* to 16*plus*). In the 16*plus*, set:
- **GTD=Y** or **DualGTD=Y** to enable interface.
- **SendGTD=** to change IDs if necessary.

Each time a sample is to be taken, SBE 16*plus* sends following commands to GTD (ID= 01, 02, etc.):
- ***ID00VR** <CR><LF> - get GTD firmware version; wait up to 3 seconds for reply.
- ***ID00SN** <CR><LF> - get GTD serial number; wait up to 5 seconds for reply.
- ***9900P5** <CR><LF> - command all GTDs to sample pressure; hold data in GTD.
- ***ID00DB** <CR.<LF> - get held pressure; wait up to 90 seconds for reply.
- ***9900Q5** <CR><LF> - command all GTDs to sample temperature; hold data in GTD.
- ***ID00DB** <CR.<LF> - get held temperature; wait up to 90 seconds for reply.

Notes:
- A 16*plus* with dual GTDs is shipped with a Y-cable installed for the GTDs. The GTD ends are labeled GTD #1 and #2, and Sea-Bird set the GTD IDs to match.
- If **DualGTD=Y**, setting for **GTD=** has no effect.

GTD=x
x=Y: Enable RS-232 GTD.
x=N: Do not enable GTD.

DualGTD=x
x=Y: Enable dual (2) GTDs.
x=N: Do not enable dual GTDs.

TGTD
Measure GTD(s), output 1 sample of data from each GTD (firmware version, serial number, pressure, and temperature).

Example: Output GTD data for system with dual GTDs (user input in bold):

```
S>TGTD
GTD#1 VR reply = *0001VR=s2.03    (GTD firmware version)
GTD#2 VR reply = *0002VR=s2.03    (GTD firmware version)
GTD#1 SN reply = *0001SN = 75524    (GTD serial number)
GTD#2 SN reply = *0002SN = 81440    (GTD serial number)
GTD#1 pressure reply = *00011010.04661, p = 101004661  (millibars x 10^5)
GTD#2 pressure reply = *00021010.01580, p = 101001580  (millibars x 10^5)
GTD#1 temperature reply = *000123.49548, t = 23.4955    (°C)
GTD#2 temperature reply = *000223.0357038, t = 23.0357  (°C)
```

SendGTD=command
Command 16*plus* to send **command** to GTD and receive response; **command** can be any command recognized by GTD (see GTD manual).

Examples: (user input in bold)

Send firmware version command to GTD #1:

```
S>SENDGTD=*0100vr
Sending GTD: **0100vr
GTD RX = *0001VR=s2.03
```

Send serial number command to GTD #2:

```
S>SENDGTD=*0200sn
Sending GTD: **0200sn
GTD RX = *0002SN=81440
```

Autonomous Sampling (logging) Commands

Notes:
- In SEATERM, to save real-time data to a file, click Capture on the Toolbar before beginning logging.
- If the FLASH memory is filled to capacity, data sampling and transmission of real-time data (if programmed) continue, but excess data is not saved in memory.
- If the 16*plus* is sampling and the voltage is less than the cut-off voltage (7.5 volts) for five consecutive scans, the 16*plus* halts logging and displays `WARNING: LOW BATTERY VOLTAGE` in response to the status command (**DS**).

Autonomous sampling commands direct the SBE 16*plus* to sample at pre-programmed intervals. When commanded to start sampling with **StartNow** or **StartLater**, the 16*plus* takes samples, stores the data in its FLASH memory, transmits real-time data (if **TxRealTime=Y**), and enters quiescent (sleep) state between samples.

To start sampling, use **StartNow** or **StartLater**. Sampling starts approximately 5 seconds after receipt of **StartNow**. The first time sampling starts after receipt of initialize logging (**InitLogging**), data recording starts at the beginning of memory and any previously recorded data is written over. When **Stop** is sent, recording stops. Each time **StartNow** or **StartLater** is sent again, recording continues, with new data stored after previously recorded data. A new header is written each time sampling starts and every 1000 samples thereafter.

The SBE 16*plus* responds only to **DS**, **DCal**, **TS**, **SL**, **SLT**, **QS**, and **Stop** while sampling. If you wake the 16*plus* (for example, to send **DS** to check progress), it temporarily stops sampling. Sampling resumes when it goes back to sleep again (either by sending **QS** or after 2-minute timeout).

Note:
NCycles=, **ParosIntegration=** and **DelayBeforeSampling=** affect the time required to sample. If these are too high, the 16*plus* is unable to take the required number of measurements and do the calculations within **SampleInterval=**. When it is beginning to log, the 16*plus* checks all parameters, and if necessary it internally increases **SampleInterval=**.

SampleInterval=x — **x**= interval (seconds) between samples (10 - 14,400 seconds).

Example: If **SampleInterval=10** and **NCycles=4**, every 10 seconds 16*plus* takes 4 measurements (each 0.25 seconds apart), averages data from measurements, and stores averaged data in FLASH memory.

StartNow — Start autonomous sampling now.

StartMMDDYY=mmddyy — Set delayed start month, day, and year.

StartDDMMYY=ddmmyy — Set delayed start day, month, and year.

StartHHMMSS=hhmmss — Set delayed start hour, minute, and second.

StartLater — Start autonomous sampling at delayed start date and time.

Notes:
- **StartDDMMYY=** or **StartMMDDYY=** must be followed by **StartHHMMSS=** to set delayed start time.
- **StartDDMMYY=** and **StartMMDDYY=** are equivalent. Either can be used to set delayed start time.
- After receiving **StartLater**, the 16*plus* displays `waiting to start at...` in reply to **DS**. Once sampling starts, the **DS** reply displays `logging`.
- If the delayed start time has already passed when **StartLater** is received, the 16*plus* executes **StartNow**.

Example: Program 16*plus* to start logging on 20 January 2005 12:00:00 (user input in bold).

```
S>STARTMMDDYY=012005
S>STARTHHMMSS=120000
S>STARTLATER
```

or

```
S>STARTDDMMYY=200105
S>STARTHHMMSS=120000
S>STARTLATER
```

Stop — Stop autonomous sampling or stop waiting to start autonomous sampling (if **StartLater** was sent but sampling has not begun yet). Press Enter key to get S> prompt before entering **Stop**.

Notes:
- You may need to send **Stop** several times to get the 16*plus* to respond.
- You must stop sampling before uploading data.

Polled Sampling Commands

Notes:
- The 16*plus* has a buffer that stores the most recent data samples. Unlike data in the FLASH memory, data in the buffer is erased upon removal or failure of power.
- *Leave power on* in **SL**, **SLT**, **TS**, and **TSSOn** descriptions refers to power for the 16*plus* as well as for a pump and any auxiliary sensors. Power remains on until **QS** is sent or the instrument times out (after 2 minutes).

These commands request a single sample. The SBE 16*plus* always stores data for the most recent sample in its buffer. Some Sampling commands also store data in FLASH memory - the 16*plus* will not execute the *store data in FLASH memory* portion of those commands while sampling autonomously.

SL	Output last sample from buffer (sample obtained with polled sampling command, or latest sample from autonomous sampling), and leave power on.
SLT	Output last sample from buffer, then take new sample and store data in buffer. Leave power on. **Data is not stored in FLASH memory**.
TS	Take new sample, store data in buffer, output data, and leave power on. **Data is not stored in FLASH memory**.
TSS	Take new sample, **store data in buffer and FLASH memory**, output data, and turn power off.
TSSOn	Take new sample, **store data in buffer and FLASH memory**, output data, and leave power on.

Serial Line Sync Commands

Note:
See *Sampling Modes* for details.

SyncMode=x	**x=Y**: Enable serial line synchronization. When RS-232 RX line is high (3-10 VDC) for 1 to 1000 milliseconds, 16*plus* takes a sample, stores data in FLASH memory, transmits real-time data (if **TxRealTime=Y**), and powers down. **x=N**: Disable serial line synchronization.
SyncWait=x	**x**= time (in seconds) 16*plus* monitors RS-232 line for commands after taking a sample in serial line sync mode. Range 0 to 120 seconds; default 0 seconds.

Data Upload Commands

Notes:
- **Use Upload on the Toolbar or Upload Data in the Data menu to upload data that will be processed by SBE Data Processing**. Manually entering **DDb,e** does not produce data with the required header information for processing by our software. These commands are included here for reference for users who are writing their own software.
- To save data to a file, click Capture on the Toolbar before entering **DDb,e** or **DHb,e**.
- See *Data Output Formats*.

Stop sampling autonomously before uploading data.

DDb,e

Upload data from sample **b** to sample **e**. If **b** and **e** are omitted, all data is uploaded. First sample is number 1.

Example: Upload samples 1 - 199 to a file (user input in bold):
(Click Capture on Toolbar and enter desired filename in dialog box.)
S>**DD1,199**

DHb,e

Upload header **b** to header **e**. If **b** and **e** are omitted, all headers are uploaded. First header is number 1. Header includes:
- header number
- month, day, hour, minute, and second when header was written
- first and last sample for header
- interval between samples (**SampleInterval=**)
- reason logging was halted (batfail = battery voltage too low; stop cmd = received **Stop** command or Home or Ctrl Z character; timeout = error condition; unknown = error condition; ?????? = error condition)

Example: Upload second header to a file (user input in bold):
(Click Capture on Toolbar and enter desired filename in dialog box.)
S>**DH2**

16*plus* responds:
```
hdr 2 30 Nov 2005 12:30:33 samples 35 to 87, int=60, stop=stop cmd
```

Testing Commands

Note:
If your 16plus includes an optional pump:
Testing commands do not automatically turn the pump on. Thus, for instruments plumbed with the pump, they report data from essentially the same sample of water for all 100 measurements, because the pump does not run but the pump and associated plumbing prevent water from freely flowing through the conductivity cell and other plumbed sensors (for example, dissolved oxygen sensor). To get data from fresh samples, send **PumpOn** before sending a testing command, and then send **PumpOff** when the test is complete.

The SBE 16*plus* takes and outputs **100 samples** for each test (except as noted); data is **not** stored in FLASH memory. Press the Esc key or Stop on the Toolbar to stop a test.

TT — Measure temperature, output converted data.

TC — Measure conductivity, output converted data.

TP — Measure internally mounted pressure (strain gauge or Quartz), output converted data.

TV — Measure four external voltage channels, output converted data.

TF — Measure frequency (internally mounted Quartz pressure sensor), output converted data.

T38 — Measure SBE 38 (secondary temperature), output converted data.

T50 — Measure SBE 50 pressure, output converted data.

TTR — Measure temperature, output raw data.

TCR — Measure conductivity, output raw data.

TPR — Measure internally mounted pressure (strain gauge or Quartz), output raw data.

TVR — Measure voltages read by A/D converter, output raw data:

Column	Output
1	Main battery voltage / 11
2	Back-up lithium battery voltage / 3.741
3	External current / 333.33
4	Pressure temperature voltage
5 – 8	External voltages

TFR — Measure frequency (internally mounted Quartz pressure sensor), output raw data.

PumpOn — Turn pump on for testing purposes. Use this command:
- Before sending testing command to obtain pumped data from sensors plumbed with the pump, or
- To test pump.

PumpOff — Turn pump off for testing purposes.

Calibration Coefficients Commands

Notes:
- Dates shown are when calibrations were performed. Calibration coefficients are initially factory-set and should agree with Calibration Certificate shipped with 16*plus*.
- See individual Coefficient Commands below for definitions of the data in the example.

DCal Display calibration coefficients. Equivalent to Coefficients on Toolbar.

Example: Display coefficients for 16*plus* with an internally mounted Quartz pressure sensor (user input in bold).

```
S>dcal
SeacatPlus V 1.8c  SERIAL NO. 4300  25 Jul 2007  14:46:05
temperature:  01-aug-03
    TA0 = -3.178124e-06
    TA1 = 2.751603e-04
    TA2 = -2.215606e-06
    TA3 = 1.549719e-07
    TOFFSET = 0.000000e+00
conductivity:  01-aug-03
    G = -9.855242e-01
    H = 1.458421e-01
    I = -3.290801e-04
    J = 4.784952e-05
    CF0 = 2.584100e+03          (not used in calculations; ignore)
    CPCOR = -9.570000e-08
    CTCOR = 3.250000e-06
    CSLOPE = 1.000000e+00
pressure S/N , range = 2000 psia:  14-jul-04
    PC1 = 0.000000e+00
    PC2 = 0.000000e+00
    PC3 = 0.000000e+00
    PD1 = 0.000000e+00
    PD2 = 0.000000e+00
    PT1 = 0.000000e+00
    PT2 = 0.000000e+00
    PT3 = 0.000000e+00
    PT4 = 0.000000e+00
    PSLOPE = 1.000000e+00
    POFFSET = 0.000000e+00
volt 0: offset = 0.000000e+00, slope = 1.000000e+00
volt 1: offset = 0.000000e+00, slope = 1.000000e+00
volt 2: offset = 0.000000e+00, slope = 1.000000e+00
volt 3: offset = 0.000000e+00, slope = 1.000000e+00
    EXTFREQSF = 1.000000e+00
```

Calibration Coefficients Commands (*continued*)

The individual commands listed below are used to modify a particular coefficient or date:

Notes:
- F = floating point number
  S = string with no spaces
- If using an SBE 38 secondary temperature sensor or SBE 50 pressure sensor, its calibration coefficients are not stored in the 16*plus* EEPROM. View and/or modify the instrument's calibration coefficients by connecting the instrument to the computer directly and using SEATERM.
- If using auxiliary A/D sensors (**Volt0=** through **Volt3=**), their calibration coefficients are not stored in the 16*plus* EEPROM, but are stored in the 16*plus* configuration (.con) file. View and/or modify the calibration coefficients using the Configure menu in SBE Data Processing or the Configure Inputs menu in SEASAVE.

Temperature

TCalDate=S	**S=**calibration date
TA0=F	**F=**A0
TA1=F	**F=**A1
TA2=F	**F=**A2
TA3=F	**F=**A3
TOffset=F	**F=**offset correction

Conductivity

CCalDate=S	**S=**calibration date
CG=F	**F=**G
CH=F	**F=**H
CI=F	**F=**I
CJ=F	**F=**J
CPCOR=F	**F=**pcor
CTCOR=F	**F=**tcor
CSlope=F	**F=**slope correction

Internally Mounted Pressure - General

PCalDate=S	**S=**calibration date
PRange=F	**F=**sensor full scale range (psi)
POffset=F	**F=**offset correction

Internally Mounted Strain Gauge Pressure

PA0=F	**F=**A0
PA1=F	**F=**A1
PA2=F	**F=**A2
PTempA0=F	**F=**pressure temperature A0
PTempA1=F	**F=**pressure temperature A1
PTempA2=F	**F=**pressure temperature A2
PTCA0=F	**F=**pressure temperature compensation ptca0
PTCA1=F	**F=**pressure temperature compensation ptca1
PTCA2=F	**F=**pressure temperature compensation ptca2
PTCB0=F	**F=**pressure temperature compensation ptcb0
PTCB1=F	**F=**pressure temperature compensation ptcb1
PTCB2=F	**F=**pressure temperature compensation ptcb2

Internally Mounted Quartz Pressure

PC1=F	**F=**C1
PC2=F	**F=**C2
PC3=F	**F=**C3
PD1=F	**F=**D1
PD2=F	**F=**D2
PT1=F	**F=**T1
PT2=F	**F=**T2
PT3=F	**F=**T3
PT4=F	**F=**T4
PSlope=F	**F=**slope correction

External Frequency

ExtFreqSF=F	**F=**external frequency scale factor (applies to internally mounted Quartz pressure sensor)

Data Output Formats

Note:
For the date and time output with the data, time is the time at the **start** of the sample, after:
- a small amount of time (1 to 2 seconds) for the 16*plus* to wake up and prepare to sample, and
- any programmed **DelayBeforeSampling=**.

For example, if the 16*plus* is programmed to wake up and sample at 12:00:00, and **DelayBeforeSampling=20**, the output time for the first sample will be 12:00:21 or 12:00:22.

The SBE 16*plus* stores data in a compact machine code. Data is converted and output in the user-selected format without affecting data in memory. Because memory data remains intact until deliberately overwritten, you can upload in one format, then choose another format and upload again.

Output format is dependent on **OutputFormat= (0, 1, 2, 3, 4, or 5)**, as detailed in the following sections. The inclusion of some data is dependent on the system configuration - if the system does not include the specified sensor, the corresponding data is not included in the output data stream, shortening the data string.

Notes:
- If you will be using SEASAVE to acquire real-time data, you must set **OutputFormat=0**.
- When using SEATERM's Upload button, SEATERM sends **OutputFormat=0**. This causes the 16*plus* to upload data in memory in raw hex, regardless of the user-programmed format, providing the data in a format that Sea-Bird's data processing software can use.
- Our software uses the equations shown to perform these calculations; alternatively, you can use the equations to develop your own processing software.
- The internally mounted pressure sensor is an absolute sensor, so its **raw** output includes the effect of atmospheric pressure (14.7 psi). As shown on the Calibration Sheet, Sea-Bird's calibration (and resulting calibration coefficients) is in terms of psia. However, when outputting pressure in **engineering units**, the 16*plus* outputs pressure relative to the ocean surface (i.e., at the surface the output pressure is 0 decibars). The 16*plus* uses the following equation to convert psia to decibars:
  pressure (db) =
  [pressure (psia) - 14.7] * 0.689476
- Although **OutputFormat=0** outputs *raw* data for temperature, conductivity, etc., it outputs engineering units for SBE 38, SBE 50, and GTD data.
  SBE 50 units are dependent on **OutputFormat=** programmed into the SBE 50.

OutputFormat=0 (raw frequencies and voltages in Hex)

Data is output in the order listed, with no spaces or commas between parameters. Shown with each parameter is the number of digits, and how to calculate the parameter from the data (use the decimal equivalent of the hex data in the equations).

1. Temperature
   A/D counts = ttttt
2. Conductivity
   conductivity frequency (Hz) = cccccc / 256
3. Internally mounted strain gauge pressure sensor pressure (if **PType=1**)
   A/D counts = pppppp
4. Internally mounted strain gauge pressure sensor pressure temperature compensation (if **PType=1**)
   pressure temperature compensation voltage = vvvv / 13,107
5. Internally mounted Quartz pressure sensor pressure (if **PType=3**)
   pressure frequency (Hz) = pppppp / 256
6. Internally mounted Quartz pressure sensor temperature compensation (if **PType=3**)
   temperature compensation voltage = vvvv / 13,107
7. External voltage 0 (if **Volt0=Y**)
   external voltage 0= vvvv / 13,107
8. External voltage 1 (if **Volt1=Y**)
   external voltage 1 = vvvv / 13,107
9. External voltage 2 (if **Volt2=Y**)
   external voltage 2 = vvvv / 13,107
10. External voltage 3 (if **Volt3=Y**)
    external voltage 3 = vvvv / 13,107
11. SBE 38 secondary temperature (if **SBE38=Y**)
    SBE 38 temperature (°C, ITS-90) = (ttttt / 100,000) – 10
12. SBE 50 strain gauge pressure (if **SBE50=Y**)
    SBE 50 pressure (decibars, psia, meters, or feet) = (pppppp / 10,000) - 100
13. GTD #1 pressure (if **GTD=Y** or **DualGTD=Y**)
    GTD #1 pressure (millibars) = pppppppp / 100,000
14. GTD #1 temperature (if **GTD=Y** or **DualGTD=Y**)
    GTD #1 temperature (°C, ITS-90) = (ttttt / 100,000) - 10
15. GTD #2 pressure (if **DualGTD=Y**)
    GTD #2 pressure (millibars) = pppppppp / 100,000
16. GTD #2 temperature (if **DualGTD=Y**)
    GTD #2 temperature (°C, ITS-90) = (ttttt / 100,000) - 10
17. Time
    seconds since January 1, 1980 = ssssssss

Example: 16*plus* with internally mounted strain gauge pressure sensor and 2 external voltages sampled, example scan = ttttttccccccppppppvvvvvvvvvvvvssssssss
= 0A53711BC7220C14C17D820305059425980600

- Temperature = ttttt = 0A5371 (676721 decimal);
  temperature A/D counts = 676721
- Conductivity = 1BC722 (1820450 decimal);
  conductivity frequency = 1820450 / 256 = 7111.133 Hz
- Internally mounted strain gauge pressure = pppppp = 0C14C1 (791745 decimal);
  Strain gauge pressure A/D counts = 791745
- Internally mounted strain gauge temperature compensation = vvvv = 7D82 (32,130 decimal);
  Strain gauge temperature = 32,130 / 13,107 = 2.4514 volts
- First external voltage = vvvv = 0305 (773 decimal); voltage = 773 / 13,107 = 0.0590 volts
- Second external voltage = vvvv = 0594 (1428 decimal); voltage = 1428 / 13,107 = 0.1089 volts
- Time = ssssssss = 25980600 (630,720,000 decimal)
  seconds since January 1, 1980 = 630,720,000

OutputFormat=1 (engineering units in Hex)

Data is output in the order listed, with no spaces or commas between the parameters. Shown with each parameter is the number of digits, and how to calculate the parameter from the data (use the decimal equivalent of the hex data in the equations).

1. Temperature
   temperature (°C, ITS-90) = (ttttt / 100,000) - 10
2. Conductivity
   Conductivity (S/m) = (cccccc / 1,000,000) - 1
3. Internally mounted pressure (Quartz or strain gauge - **PType=1** or **3**)
   pressure (decibars) = (pppppp / 1,000) - 100
4. External voltage 0 (if **Volt0=Y**)
   external voltage 0= vvvv / 13,107
5. External voltage 1 (if **Volt1=Y**)
   external voltage 1 = vvvv / 13,107
6. External voltage 2 (if **Volt2=Y**)
   external voltage 2 = vvvv / 13,107
7. External voltage 3 (if **Volt3=Y**)
   external voltage 3 = vvvv / 13,107
8. SBE 38 secondary temperature (if **SBE38=Y**)
   SBE 38 temperature (°C, ITS-90) = (ttttt / 100,000) – 10
9. SBE 50 strain gauge pressure (if **SBE50=Y**)
   SBE 50 pressure (decibars, psia, meters, or feet) = (pppppp / 10,000) - 100
10. GTD #1 pressure (if **GTD=Y** or **DualGTD=Y**)
    GTD #1 pressure (millibars) = pppppppp / 100,000
11. GTD #1 temperature (if **GTD=Y** or **DualGTD=Y**)
    GTD #1 temperature (°C, ITS-90) = (ttttt / 100,000) - 10
12. GTD #2 pressure (if **DualGTD=Y**)
    GTD #2 pressure (millibars) = pppppppp / 100,000
13. GTD #2 temperature (if **DualGTD=Y**)
    GTD #2 temperature (°C, ITS-90) = (ttttt / 100,000) - 10
14. Time
    seconds since January 1, 1980 = ssssssss

Note:
SBE 50 units are dependent on **OutputFormat=** programmed into the SBE 50.

Example: 16*plus* with internally mounted strain gauge pressure sensor and 2 external voltages sampled, example scan = ttttttccccccppppppvvvvvvvvssssssss
= 3385C40F42FE0186DE0305059425980600

- Temperature = ttttt = 3385C4 (3376580 decimal);
  temperature (°C, ITS-90) = (3376580 / 100,000) - 10 = 23.7658
- Conductivity = cccccc = 0F42FE (1000190 decimal);
  conductivity (S/m) = (1000190 / 1,000,000) - 1 = 0.00019
- Internally mounted pressure = pppppp = 0186DE (100062 decimal);
  pressure (decibars) = (100062 / 1,000) - 100 = 0.062
- First external voltage = vvvv = 0305 (773 decimal); voltage = 773 / 13,107 = 0.0590 volts
- Second external voltage = vvvv = 0594 (1428 decimal); voltage = 1428 / 13,107 = 0.1089 volts
- Time = ssssssss = 25980600 (630,720,000 decimal)
  seconds since January 1, 1980 = 630,720,000

OutputFormat=2 (raw frequencies and voltages in decimal)

Data is output in the order listed, with a comma followed by a space between each parameter. Shown with each parameter are the number of digits and the placement of the decimal point. Leading zeros are suppressed, except for one zero to the left of the decimal point.

1. Temperature
   A/D counts = ttttt
2. Conductivity
   conductivity frequency (Hz) = cccc.ccc
3. Internally mounted strain gauge pressure sensor pressure (if **PType=1**)
   A/D counts = pppppp
4. Internally mounted strain gauge pressure sensor pressure temperature compensation (if **PType=1**)
   pressure temperature compensation voltage = v.vvvv
5. Internally mounted Quartz pressure sensor pressure (if **PType=3**)
   Quartz pressure frequency (Hz) = ppppp.ppp
6. Internally mounted Quartz pressure sensor temperature compensation (if **PType=3**)
   Quartz temperature compensation voltage = v.vvvv
7. External voltage 0 (if **Volt0=Y**)
   external voltage 0= v.vvvv
8. External voltage 1 (if **Volt1=Y**)
   external voltage 1 = v.vvvv
9. External voltage 2 (if **Volt2=Y**)
   external voltage 2 = v.vvvv
10. External voltage 3 (if **Volt3=Y**)
    external voltage 3 = v.vvvv
11. SBE 38 secondary temperature (if **SBE38=Y**)
    SBE 38 temperature (°C, ITS-90) = ttt.tttt
12. SBE 50 strain gauge pressure (if **SBE50=Y**)
    SBE 50 pressure (decibars, psia, meters, or feet) = pppp.ppp
13. GTD #1 pressure (if **GTD=Y** or **DualGTD=Y**)
    GTD #1 pressure (millibars) = pppppppppp / 100,000
14. GTD #1 temperature (if **GTD=Y** or **DualGTD=Y**)
    GTD #1 temperature (°C, ITS-90) = tt.ttt
15. GTD #2 pressure (if **DualGTD=Y**)
    GTD #2 pressure (millibars) = pppppppppp / 100,000
16. GTD #2 temperature (if **DualGTD=Y**)
    GTD #2 temperature (°C, ITS-90) = tt.ttt
17. Time
    date, time = dd mmm yyyy, hh:mm:ss (day month year hour:minute:second)

Notes:
- Although **OutputFormat=2** outputs *raw* data for temperature, conductivity, etc., it outputs engineering units for SBE 38, SBE 50, and GTD data.
- SBE 50 units are dependent on **OutputFormat=** programmed into the SBE 50.

Example: 16*plus* with internally mounted strain gauge pressure sensor and 2 external voltages sampled,
example scan = ttttt, cccc.ccc, pppppp, v.vvvv, v.vvvv, v.vvvv, dd mmm yyyy, hh:mm:ss
= 676721, 7111.133, 791745, 2.4514, 0.0590, 0.1089, 12 nov 2000, 12:23:05

- Temperature = ttttt = 676721;
  temperature A/D counts = 676721
- Conductivity = cccc.ccc = 7111.133;
  conductivity frequency = 7111.133 Hz
- Internally mounted strain gauge pressure = pppppp = 791745;
  Strain gauge pressure A/D counts = 791745
- Internally mounted strain gauge temperature compensation = v.vvvv = 2.4514;
  Strain gauge temperature = 2.4514 volts
- First external voltage = v.vvvv = 0.0590; voltage = 0.0590 volts
- Second external voltage = v.vvvv = 0.1089; voltage = 0.1089 volts
- Date, time = dd mmm yyyy, hh:mm:ss = 12 nov 2000, 12:23:05
  Date, time = 12 November 2000, 12:23:05

OutputFormat=3 (engineering units in decimal)

Data is output in the order listed, with a comma followed by a space between each parameter. Shown with each parameter are the number of digits and the placement of the decimal point. Leading zeros are suppressed, except for one zero to the left of the decimal point.

Uploaded Data (from DDb,e):

1. Temperature
   temperature (°C, ITS-90) = ttt.tttt
2. Conductivity
   Conductivity (S/m) = cc.ccccc
3. Internally mounted pressure (Quartz or strain gauge - **PType=1** or **3**)
   pressure (decibars) = pppp.ppp
4. External voltage 0 (if **Volt0=Y**)
   external voltage 0= v.vvvv
5. External voltage 1 (if **Volt1=Y**)
   external voltage 1 = v.vvvv
6. External voltage 2 (if **Volt2=Y**)
   external voltage 2 = v.vvvv
7. External voltage 3 (if **Volt3=Y**)
   external voltage 3 = v.vvvv
8. SBE 38 secondary temperature (if **SBE38=Y**)
   SBE 38 temperature (°C, ITS-90) = ttt.tttt
9. SBE 50 strain gauge pressure (if **SBE50=Y**)
   SBE 50 pressure (decibars, psia, meters, or feet) = pppp.ppp
10. GTD #1 pressure (if **GTD=Y** or **DualGTD=Y**)
    GTD #1 pressure (millibars) = pppppppppp / 100,000
11. GTD #1 temperature (if **GTD=Y** or **DualGTD=Y**)
    GTD #1 temperature (°C, ITS-90) = tt.ttt
12. GTD #2 pressure (if **DualGTD=Y**)
    GTD #2 pressure (millibars) = pppppppppp / 100,000
13. GTD #2 temperature (if **DualGTD=Y**)
    GTD #2 temperature (°C, ITS-90) = tt.ttt
14. Salinity (if **OutputSal=Y**)
    salinity (psu) = sss.ssss
15. Sound velocity (if **OutputSV=Y**)
    sound velocity (meters/second) = vvvv.vvv
16. Time
    date, time = dd mmm yyyy, hh:mm:ss (day month year hour:minute:second)

Note:
SBE 50 units are dependent on **OutputFormat=** programmed into the SBE 50.

Example: 16*plus* with internally mounted strain gauge pressure sensor and 2 external voltages sampled, example scan = ttt.tttt, cc.ccccc, pppp.ppp, v.vvvv, v.vvvv, dd mmm yyyy, hh:mm:ss
= 23.7658, 0.00019, 0.062, 0.0590, 0.1089, 12 nov 2000, 12:23:05

- Temperature = ttt.tttt = 23.7658;
  temperature (°C, ITS-90) = 23.7658
- Conductivity = cc.ccccc = 0.00019;
  conductivity (S/m) = 0.00019
- Internally mounted pressure = pppp.ppp = 0.062;
  pressure (decibars) = 0.062
- First external voltage = v.vvvv = 0.0590; voltage = 0.0590 volts
- Second external voltage = v.vvvv = 0.1089; voltage = 0.1089 volts
- Date, time = dd mmm yyyy, hh:mm:ss = 12 nov 2000, 12:23:05
  Date, time = 12 November 2000, 12:23:05

Polled Data from SL, SLT, TS, TSS, or TSSOn:
If **OutputUCSD=Y** and the 16*plus* is logging (autonomous sampling is in progress), data is followed by density sigma-t in kg/m^3 (ddd.dddd), battery voltage (vv.v), and operating current in mA (ccc.c), each separated by a comma and a space. The rest of the data stream is as described above for uploaded data.

OutputFormat=4 (engineering units in decimal, in XML)

Data is output in the order listed, with a carriage return and line feed between each parameter. Shown with each parameter are the number of digits and the placement of the decimal point. Leading zeros are suppressed, except for one zero to the left of the decimal point.

Uploaded Data (from DDb,e):

```
<datapacket>
<hdr>
<mfg>Sea-Bird</mfg>
<model>16plus</model>
<sn>nnnn</sn>
</hdr>
<data>
<t1>ttt.tttt</t1>
<c1>cc.ccccc</c1>
<p1>pppp.ppp </p1>                          (if PType=1 or 3)
<v0>v.vvvv</v0>                            (if Volt0=Y)
<v1>v.vvvv</v1>                            (if Volt1=Y)
<v2>v.vvvv</v2>                            (if Volt2=Y)
<v3>v.vvvv</v3>                            (if Volt3=Y)
<t38>ttt.tttt</t38>                        (if SBE38=Y)
<p2>pppp.ppp</p2>                          (if SBE50=Y)
<gtdp1>pppppppppp</gtdp1>                  (if GTD=Y or DualGTD=Y)
<gtdt1>tt.ttt</gtdt1>                      (if GTD=Y or DualGTD=Y)
<gtdp2>pppppppppp</gtdp2>                  (if DualGTD=Y)
<gtdt2>tt.ttt</gtdt2>                      (if DualGTD=Y)
<sal>sss.ssss</sal>                        (if OutputSal=Y)
<sv>vvvv.vvv</sv>                          (if OutputSV=Y)
<dt>yyyymmddThh:mm:ss</dt>
</data>
</datapacket>
```

where

Serial number = nnnn
Temperature (°C, ITS-90) = ttt.tttt
Conductivity (S/m) = cc.ccccc
Internally mounted pressure (decibars) = pppp.ppp
External voltage = v.vvvv (for voltage 0, 1, 2, and 3)
SBE 38 temperature (°C, ITS-90) = ttt.tttt
SBE 50 pressure (decibars, psia, meters, or feet) = pppp.ppp
GTD pressure (millibars) = pppppppppp / 100,000 (for GTD #1 and #2)
GTD temperature (°C, ITS-90) = tt.ttt (for GTD #1 and #2)
Salinity (psu) = sss.ssss
Sound velocity (meters/second) = vvvv.vvv
Date, time = year month day T hour:minute:second)

Note:
SBE 50 units are dependent on **OutputFormat=** programmed into the SBE 50.

Example: 16*plus* with internally mounted strain gauge pressure sensor and 2 external voltages sampled, example scan =

```
<datapacket>
<hdr>
<mfg>Sea-Bird</mfg>
<model>16plus</model>
<sn>1234</sn>                                  [Serial number = 1234]
</hdr>
<data>
<t1>23.7658</t1>                               [Temperature (°C, ITS-90) = 23.7658]
<c1>0.00019</c1>                               [Conductivity (S/m) = 0.00019]
<p1>0.062</p1>                                 [Internally mounted pressure (decibars) = 0.062]
<v0>0.0590</v0>                                [First external voltage = 0.0590 volts]
<v1>0.1089</v1>                                [Second external voltage = 0.1089 volts]
<dt>20060605T08:31:26</dt>                     [Date, time = June 5, 2006, 8:31:26]
</data>
</datapacket>
```

Polled Data from SL, SLT, TS, TSS, or TSSOn:
If **OutputUCSD=Y** and the 16*plus* is logging (autonomous sampling is in progress), data is followed by:
<dens>ddd.dddd</dens>
<vb>vv.v</bn>
ccc.c

where
density sigma-t (kg/m^3) = ddd.dddd
battery voltage = vv.v
operating current (mA) = ccc.c

The rest of the data stream is as described above for uploaded data.

OutputFormat=5 (engineering units in decimal, in XML, modified format)

Note:
OutputFormat=5 is listed in the status command (**DS**) response as `output format = converted XML UVIC`.

Data is output in the order listed, with **no** carriage return or line feed between each parameter. Shown with each parameter are the number of digits and the placement of the decimal point. Leading zeros are suppressed, except for one zero to the left of the decimal point.

Changes from **OutputFormat=4** are summarized as follows:
- There are no carriage returns or line feeds between each parameter.
- There is a carriage return and line feed at the end, after the </datapacket> closing tag.
- There is an <?xml version="1.0"?> tag at the beginning of the data packet.
- Data from an RS-232 auxiliary sensor is enclosed in a <ser1> tag, and a <type> tag is added to identify the type of RS-232 sensor.

Uploaded Data (from DDb,e):

Note:
For ease in reading, the data structure is shown with each XML tag on a separate line. However, there are no carriage returns or line feeds between tags (see example below).

```
<?xml version="1.0"?>
<datapacket>
<hdr>
<mfg>Sea-Bird</mfg>
<model>16plus</model>
<sn>nnnn</sn>
</hdr>
<data>
<t1>ttt.tttt</t1>
<c1>cc.ccccc</c1>
<p1>pppp.ppp </p1>                          (if PType=1 or 3)
<v0>v.vvvv</v0>                            (if Volt0=Y)
<v1>v.vvvv</v1>                            (if Volt1=Y)
<v2>v.vvvv</v2>                            (if Volt2=Y)
<v3>v.vvvv</v3>                            (if Volt3=Y)
<ser1>
<type>sbe38, sbe50, or gtd</type>          (indicates type of RS-232 sensor)
<t38>ttt.tttt</t38>                        (if SBE38=Y)
<p2>pppp.ppp</p2>                          (if SBE50=Y)
<p1>ppppppppp</p1>                         (if GTD=Y or DualGTD=Y)
<t1>tt.ttt</t1>                            (if GTD=Y or DualGTD=Y)
<p2>ppppppppp</p2>                         (if DualGTD=Y)
<t2>tt.ttt</t2>                            (if DualGTD=Y)
<ser1>
<sal>sss.ssss</sal>                        (if OutputSal=Y)
<sv>vvvv.vvv</sv>                          (if OutputSV=Y)
<dt>yyyymmddThh:mm:ss</dt>
</data>
</datapacket>
```

where

Serial number = nnnn
Temperature (°C, ITS-90) = ttt.tttt
Conductivity (S/m) = cc.ccccc
Internally mounted pressure (decibars) = pppp.ppp
External voltage = v.vvvv (for voltage 0, 1, 2, and 3)
SBE 38 temperature (°C, ITS-90) = ttt.tttt
SBE 50 pressure (decibars, psia, meters, or feet) = pppp.ppp
GTD pressure (millibars) = pppppppppp / 100,000 (for GTD #1 and #2)
GTD temperature (°C, ITS-90) = tt.ttt (for GTD #1 and #2)
Salinity (psu) = sss.ssss
Sound velocity (meters/second) = vvvv.vvv
Date, time = year month day T hour:minute:second)

Note:
SBE 50 units are dependent on **OutputFormat=** programmed into the SBE 50.

Example: 16*plus* with internally mounted strain gauge pressure sensor and 2 external voltages sampled, example scan =
<?xml version="1.0"?><datapacket><hdr><mfg>Sea-Bird</mfg><model>16plus</model><sn>1234</sn></hdr>
<data><t1>23.7658</t1><c1>0.00019</c1><p1>0.062</p1><v0>0.0590</v0><v1>0.1089</v1>
<ser1><type>gtd</type><p1>-1</p1><t1>9.999</t1></ser1><dt>20060605T08:31:26</dt></data></datapacket>CRLF

This data indicates Serial number = 1234, Temperature (°C, ITS-90) = 23.7658, Conductivity (S/m) = 0.00019,
Internally mounted pressure (decibars) = 0.062, First external voltage = 0.0590 volts,
Second external voltage = 0.1089 volts, GTD pressure (millibars) = -1, GTD temperature (°C, ITS-90) = -9.999, and
Date, time = June 5, 2006, 8:31:26

Polled Data from SL, SLT, TS, TSS, or TSSOn:
If **OutputUCSD=Y** and the 16*plus* is logging (autonomous sampling is in progress), data is followed by:
<dens>ddd.dddd</dens><vb>vv.v</bn>ccc.c

where
density sigma-t (kg/m^3) = ddd.dddd
battery voltage = vv.v
operating current (mA) = ccc.c

The rest of the data stream is as described above for uploaded data.

Setup for Deployment

1. Install new batteries or ensure the existing batteries have enough capacity to cover the intended deployment (see *Replacing Batteries* in *Section 5: Routine Maintenance and Calibration*).

2. Program the 16*plus* for the intended deployment using SEATERM (see *Section 3: Power and Communications Test* for connection information; see this section for commands):

   A. Set the date and then time.

   B. Ensure all data has been uploaded, and then send **InitLogging** to make the entire memory available for recording. If **InitLogging** is not sent, data will be stored after the last recorded sample.

   C. Establish the setup and (if applicable) autonomous sampling parameters.
   If you will be using SEASAVE to acquire and view real-time data, you must set OutputFormat=0 (raw hexadecimal).

   D. If desired, use **StartMMDDYY=**, **StartHHMMSS=**, and **StartLater** to establish delayed start date and time.

3. If you will be using SEATERM to view real-time data, click Capture on the Toolbar to save the data to a file.

4. If you will be using SEASAVE to acquire and view real-time data, verify that the configuration (.con) file matches the instrument configuration. Sea-Bird supplies a .con file to match the factory configuration and calibrations. If the instrument is recalibrated or the configuration is changed (such as by adding external sensors), the .con file must be updated to reflect the current condition. See *Verifying Contents of .con File*.

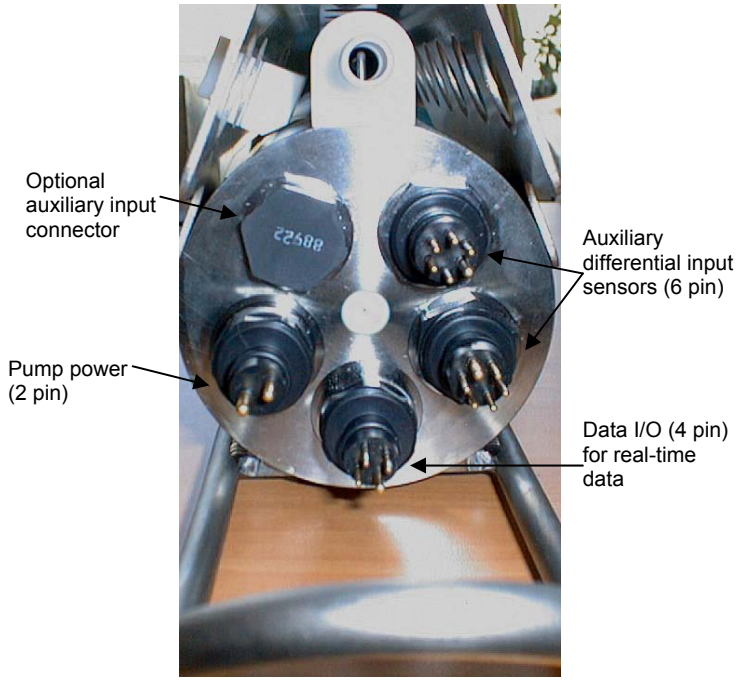
Note:
Always set date and then time. If a new date is entered but not a new time, the new date will not be saved. If a new time is entered without first entering a new date, the date will reset to the last date it was set for with **MMDDYY=** or **DDMMYY=**.

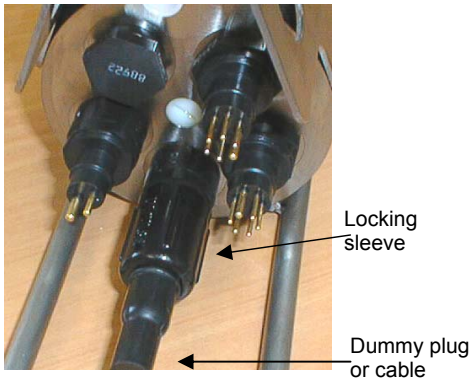
Note:
When we ship a new instrument, we include a .con file that reflects the current instrument configuration *as we know it*. The .con file is named with the instrument serial number, followed with the .con extension. For example, for an instrument with serial number 2375, Sea-Bird names the .con file *2375.con*. You may rename the .con file if desired; this will not affect the results.

Deployment

CAUTION:
Do not use WD-40 or other petroleum-based lubricants, as they will damage the connectors.

1. Install a cable or dummy plug for each connector on the 16*plus* sensor end cap:
   A. Lightly lubricate the inside of the dummy plug/cable connector with silicone grease (DC-4 or equivalent).
   B. **Standard Connector** - Install the plug/cable connector, aligning the raised bump on the side of the plug/cable connector with the large pin (pin 1 - ground) on the 16*plus*. Remove any trapped air by *burping* or gently squeezing the plug/connector near the top and moving your fingers toward the end cap. **OR**
   MCBH Connector – Install the plug/cable connector, aligning the pins.
   C. Place the locking sleeve over the plug/cable connector. Tighten the locking sleeve finger tight only. **Do not overtighten the locking sleeve and do not use a wrench or pliers.**


Optional auxiliary input connector
Auxiliary differential input sensors (6 pin)
Pump power (2 pin)
Data I/O (4 pin) for real-time data



2. Connect the other end of the cables installed in Step 1 to the appropriate sensors.

3. Verify that the hardware and external fittings are secure.

4. As applicable, remove the plug(s) from the anti-foulant device cap(s), or remove the Tygon tubing (and associated barbed anti-foulant device caps) that was looped end-to-end around the conductivity cell for storage (see *Conductivity Cell Maintenance* in *Section 5: Routine Maintenance and Calibration*). Verify that the two plastic cups contain AF24173 Anti-Foulant Devices (see *Section 5: Routine Maintenance and Calibration* for Anti-Foulant Device replacement). If using the 16*plus* with a pump, verify that the system plumbing is correctly installed (see *Configuration Options and Plumbing* in *Section 2: Description of SBE 16plus*).

5. For autonomous sampling: If not already done, send **StartNow** or **StartMMDDYY=**, **StartHHMMSS=**, and **StartLater**.

The SBE 16*plus* is ready to go into the water.

Acquiring Real-Time Data with SEASAVE

Notes:
- When we ship a new instrument, we include a .con file that reflects the current instrument configuration *as we know it*. The .con file is named with the instrument serial number, followed with the .con extension. For example, for an instrument with serial number 2375, we name the .con file *2375.con*. You may rename the .con file if desired; this will not affect the results.
- In the 16*plus* setup commands, external voltage numbers 0, 1, 2, and 3 correspond to wiring of sensors to a voltage channel on the end cap (see *Dimensions and End Cap Connectors* in *Section 2: Description of SBE 16plus*). However, in the .con file, voltage 0 is the first external voltage in the data stream, voltage 1 is the second, etc.
- SEASAVE and SBE Data Processing use the same .con file.

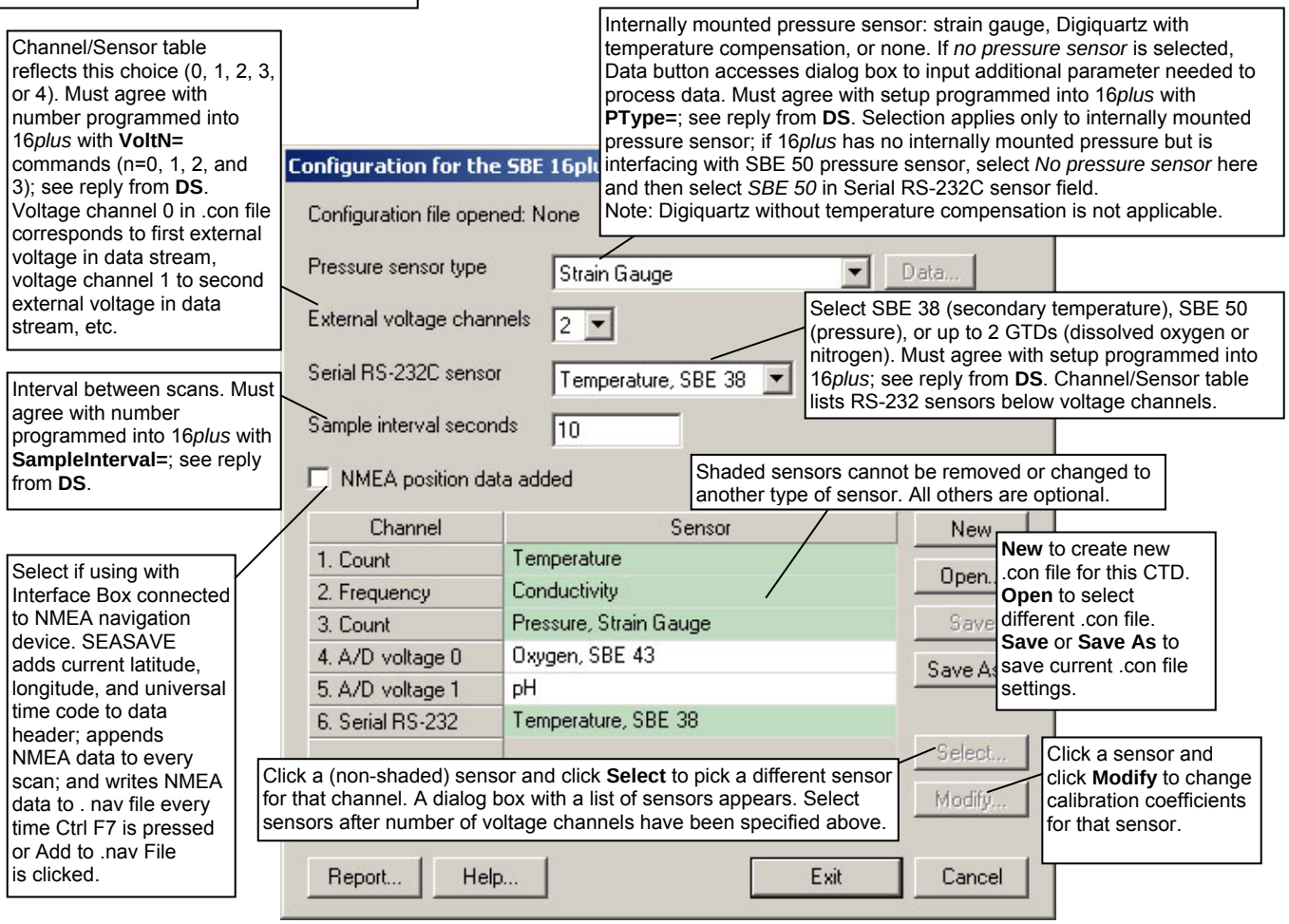
Verifying Contents of .con File

SEASAVE, our real-time data acquisition and display program, requires a .con file, which defines the instrument – integrated auxiliary sensors, and channels, serial numbers, and calibration dates and coefficients for all the sensors (conductivity, temperature, and internally mounted pressure as well as auxiliary sensors). SEASAVE (as well as our data processing software) uses the information in the .con file to interpret and process the raw data. **If the .con file does not match the actual instrument configuration, the software will be unable to interpret and process data correctly.**

1. Double click on Seasave.exe.

2. Click Configure Inputs. On the Instrument Configuration tab, click *Open*. In the dialog box, select the .con file and click Open.

3. The configuration information appears on the Instrument Configuration tab. Verify that the sensors match those on your 16*plus*, and that auxiliary sensors are assigned to the correct voltage channels. Click Modify to bring up a dialog box (shown below) to change the configuration and/or to view / modify calibration coefficients.



4. Click *Save* or *Save As* to save any changes to the .con file. Click Exit when done reviewing / modifying the .con file

Acquiring Real-Time Data

Note:
Set the baud rate on the Serial Ports tab in Configure Inputs as follows:
- 16*plus* connected directly to computer – must match baud set in 16*plus* with **Baud=**.
- 16*plus* used with 90488 RS-232 and Navigation Interface Box – must match PC baud rate set in Interface Box.

Instructions below are for an SBE 16*plus* with a conventional single-core armored cable, used without a Sea-Bird Deck Unit. **If using the SBE 16*plus* with the SEACAT/SEALOGGER RS-232 and Navigation Interface Box, see the Interface Box manual**.

1. Wiring - Terminate the single-core armored cable with an RMG-4FS connector (16*plus* with standard connectors) or MCIL-4FS (16*plus* with optional wet-pluggable connectors). Wire the cable armor to pin 1 (large pin for 16*plus* with standard connectors) and the inner conductor to pin 3 (opposite large pin) on the 16*plus* data I/O connector. On deck, wire:

Slip-ring lead	25-pin serial port	9-pin serial port
from armor	Pin 7	Pin 5
from inner conductor	Pin 3	Pin 2

2. Double click on **Seasave.exe**.

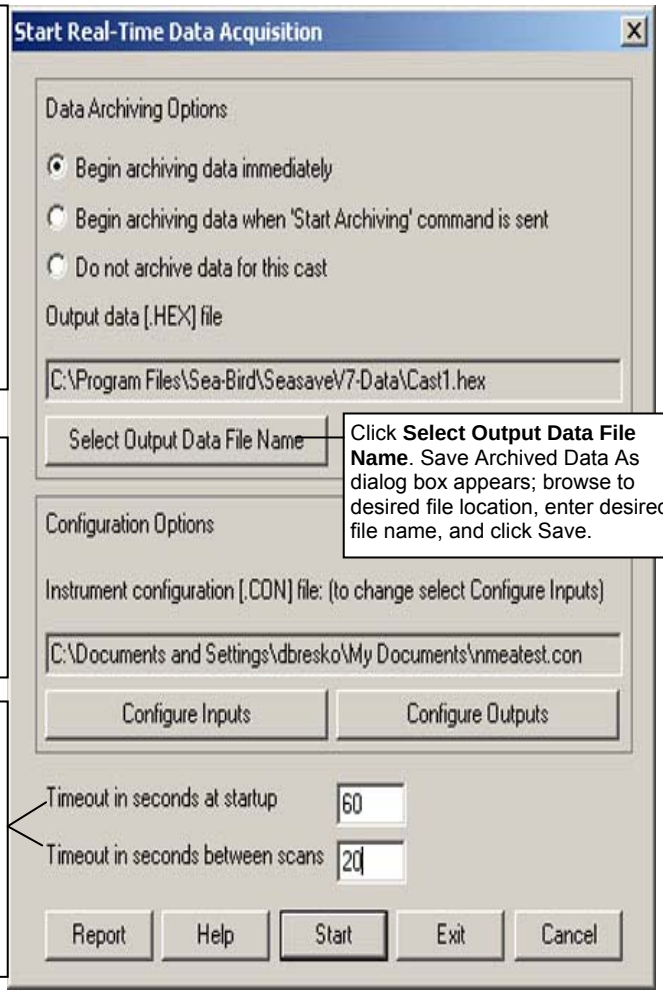
3. Perform any desired setup in the Configure Inputs, Configure Outputs, and Display menus.

4. In the Real-Time Data menu, select *Start*. The dialog box looks like this:

Data Archiving Options:
- **Begin archiving data immediately** to store raw (frequencies, A/D counts, and/or voltages) real-time data as soon as Start button is clicked and communication is established.
- **Begin archiving data when 'Start Archiving' command is sent** to control when data begins to be written to file. This allows you to eliminate scans associated with deploying CTD from ship deck and soaking instrument near surface (alternatively, remove these scans later in SBE Data Processing). If you make this selection, when you click Start button and communication is established, a dialog box with Start Archiving button appears. Click this button when ready to begin saving scans to file, or select Start Archiving in Real-Time Data menu.
- **Do not archive data for this cast** to not save data to a file. Real-time data will still appear in displays.

Configuration Options: Currently selected instrument configuration (.con) file is shown, containing information on number and type of sensors interfacing with 16*plus*, calibration coefficients, and inclusion of NMEA data with output from CTD. To select different .con file or modify input configuration (.con file, serial ports, TCP/IP ports, and/or miscellaneous), click Configure Inputs. To modify outputs (serial data output, serial ports, shared file output, mark variables, TCP/IP output, TCP/IP ports, SBE 14 remote display, header form, and/or diagnostics), click Configure Outputs.

- **Timeout in seconds at startup**: Time allowed before first data scan is received from 16*plus*. SEASAVE will *time out* and stop attempting to acquire data if data is not received from 16*plus* within this time period.
- **Timeout in seconds between scans**: Maximum **gap** allowed between scans after first data scan is received from 16*plus*. SEASAVE will *time out* and stop attempting to acquire data if data is not received from 16*plus* within this time period (for example, if a shark bites cable and interrupts data acquisition, SEASAVE stops attempting to acquire data after this gap).



Click **Select Output Data File Name**. Save Archived Data As dialog box appears; browse to desired file location, enter desired file name, and click Save.

Note:
The 16*plus* must be sampling autonomously to use SEASAVE for real-time data acquisition. Start sampling by sending **StartNow** or **StartLater** in SEATERM before starting acquisition in SEASAVE. To prevent problems in the use of the COM port, click Disconnect in SEATERM and close SEATERM before starting real-time acquisition in SEASAVE.

5. In the Start Real-Time Data Acquisition dialog box, click *Start*.
   A. If you selected *Begin archiving data immediately* or *Begin archiving data when 'Start Archiving' command is sent* above, and selected *Prompt for Header Information* in the Header Form setup (Configure Outputs), the Header Information dialog box appears. Fill in the desired header and click OK.
   B. If you selected *NMEA position data added* in the .con file, SEASAVE initializes NMEA communications.
   C. If you selected *Check Scan Length* in the Options menu, SEASAVE checks the .con file to verify that the scan length defined by the .con file matches the 16*plus* (i.e., number of sensors and inclusion of NMEA is as defined in the .con file). If a *Scan length error* appears, verify that:
      - You are using the correct .con file.
      - The .con file has been updated as necessary if you added or deleted sensors, added or deleted NMEA, etc.
   D. SEASAVE sends a message: *Waiting for data . . .* SEASAVE will *time out* if data is not received within *Timeout in seconds at startup*.
   E. The data then starts appearing in the screen displays.

6. To stop real-time data acquisition: In the Real-Time Data menu, select *Stop*. Close SEASAVE.

7. In **SEATERM**, stop logging by sending **Stop**.

Recovery

WARNING!
If the 16*plus* stops working while underwater, is unresponsive to commands, or shows other signs of flooding or damage, carefully secure it away from people until you have determined that abnormal internal pressure does not exist or has been relieved. Pressure housings may flood under pressure due to dirty or damaged o-rings, or other failed seals. When a sealed pressure housing floods at great depths and is subsequently raised to the surface, water may be trapped at the pressure at which it entered the housing, presenting a danger if the housing is opened before relieving the internal pressure. Instances of such flooding are rare. However, a housing that floods at 5000 meters depth holds an internal pressure of more than 7000 psia, and has the potential to eject the end cap with lethal force. A housing that floods at 50 meters holds an internal pressure of more then 85 psia; this force could still cause injury.
If you suspect the 16*plus* is flooded, point the 16*plus* in a safe direction away from people, and loosen 1 end cap bulkhead connector very slowly, at least 1 turn. This opens an o-ring seal under the connector. Look for signs of internal pressure (hissing or water leak). If internal pressure is detected, let it bleed off slowly past the connector o-ring. Then, you can safely remove the end cap.

Physical Handling

1. Rinse the instrument and conductivity cell with fresh water. (See *Section 5: Routine Maintenance and Calibration* for cell cleaning and storage.)

2. Reinsert the protective plugs in the anti-foulant device cups.

3. If the batteries are exhausted, new batteries must be installed before the data can be extracted. Stored data will not be lost as a result of exhaustion or removal of batteries. (See *Section 5: Routine Maintenance and Calibration* for replacement of batteries.)

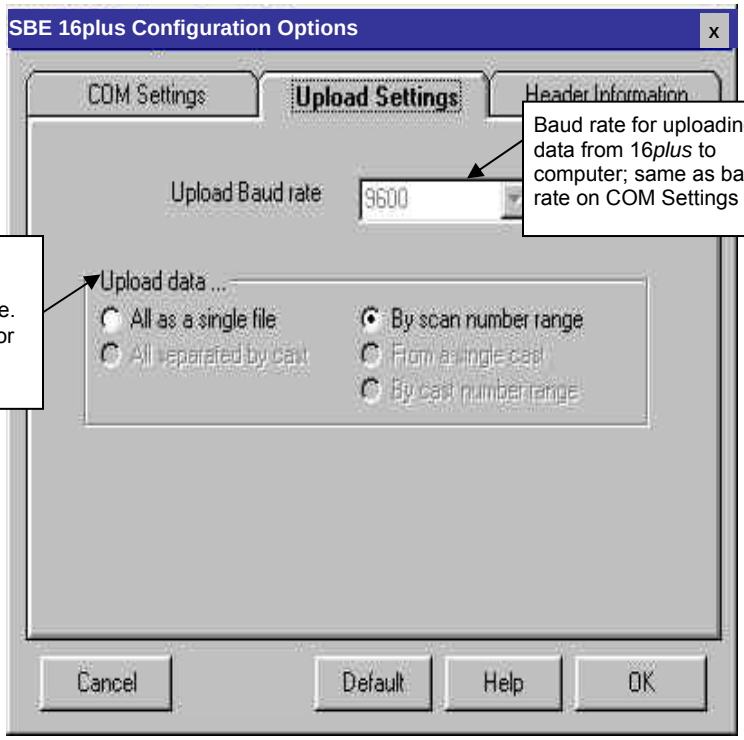
4. If immediate redeployment is not required, it is best to leave the 16*plus* with batteries in place and in a quiescent state (**QS**). Because the quiescent current required is only 30 microamps, the batteries can be left in place without significant loss of capacity.

Uploading Data

Note:
Data may be uploaded during deployment or after recovery. If uploading after recovery, connect the I/O cable as described in *Section 3: Power and Communications Test*.

1. Double click on SeaTerm.exe. The display shows the main screen.

2. In the Configure menu, select *SBE 16plus*. Click on the Upload Settings tab. The dialog box looks like this:



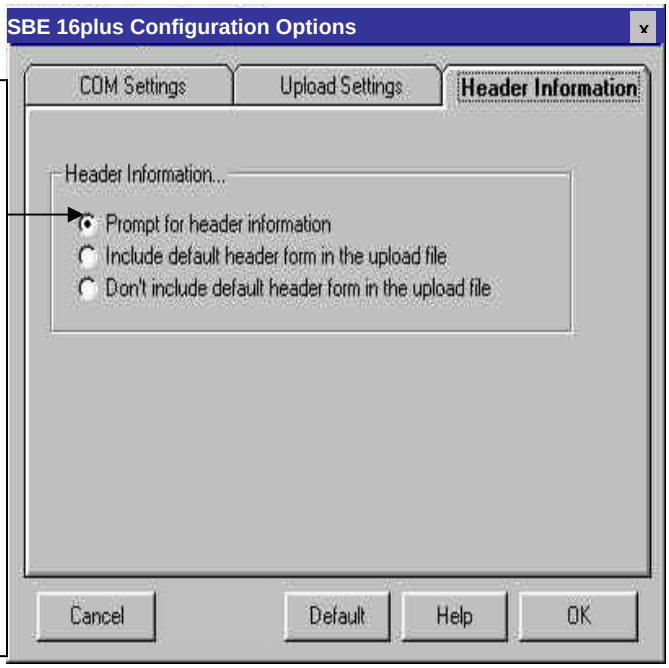
Baud rate for uploading data from 16*plus* to computer; same as baud rate on COM Settings tab.

Defines data upload type when using Upload on Toolbar or Upload Data in Data menu:
- All as single file – All data uploaded into one file.
- By scan number range – SEATERM prompts for beginning and ending scan (sample) numbers, and uploads all data within range into one file.

Note:
Set up **Upload Settings**, **Header Information**, and/or **Header Form** (Steps 2 through 4):
- The first time you upload data, and
- If you want to change upload or header parameters.

Make the selection for Upload Settings.

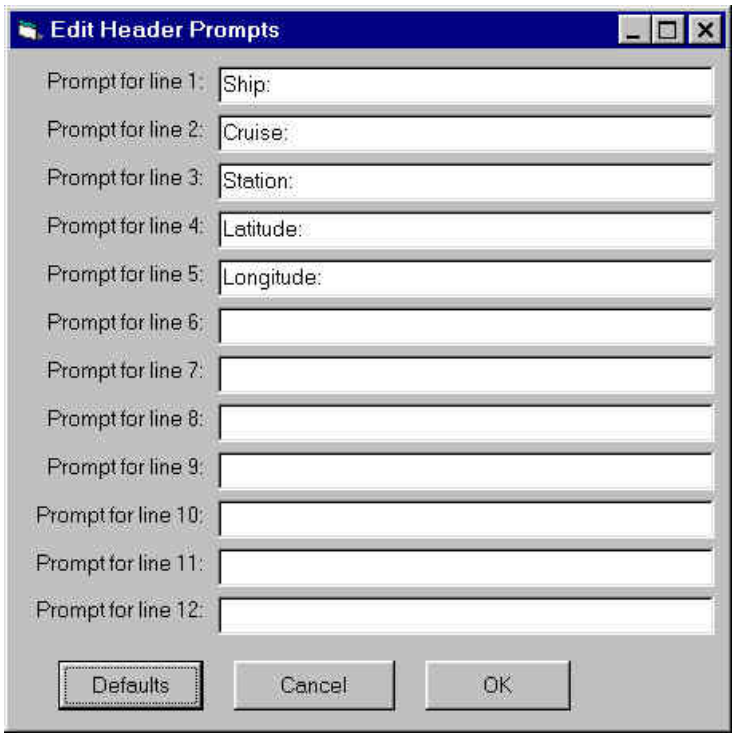
3. Click on the Header Information tab. The dialog box looks like this:



Defines header information included with uploaded data:
- Prompt for header information – Each time data is uploaded, user is prompted to fill out user-defined header form.
- Include default header form in upload file – User-defined default header form included in upload file. User is not prompted to add any information when data is uploaded.
- Don't include default header form in upload file – Header information not included in upload file.

Select the desired header information option. Click OK to save the settings.

4. In the Configure menu, select Header Form to customize the header. The dialog box looks like this (default prompts are shown):



   The entries are free form, 0 to 12 lines long. This dialog box establishes:
   - the header prompts that appear for the user to fill in when uploading data, if *Prompt for header information* was selected in the Configuration Options dialog box (Step 3)
   - the header included with the uploaded data, if *Include default header form in upload file* was selected in the Configuration Options dialog box (Step 3)

   Enter the desired header/header prompts. Click OK.

5. Click Connect on the Toolbar to begin communications with the 16*plus*. The display looks like this:

   S>

   This shows that correct communications between the computer and 16*plus* has been established.
   If the system does not respond as shown above:
   - Click Connect again.
   - Check cabling between the computer and the 16*plus*.
   - Verify the correct instrument was selected and the COM settings were entered correctly in the Configure menu.

6. Command the 16*plus* to stop autonomous sampling by pressing the Enter key and sending **Stop**.

7. Display 16*plus* status information by clicking Status on the Toolbar. The display looks like this:

```
SBE 16plus V 1.8c SERIAL NO. 4300 03 Jul 2007 14:11:48
vbatt = 10.3, vlith = 8.5, ioper = 62.5 ma, ipump = 21.6 ma,
iserial = 48.2 ma
status = not logging
sample interval = 15 seconds, number of measurements per sample = 2
samples = 823, free = 465210
run pump during sample, delay before sampling = 2.0 seconds
transmit real-time = yes
battery cutoff = 7.5 volts
pressure sensor = strain gauge, range = 1000.0
SBE 38 = no, SBE 50 = yes, Gas Tension Device = no
Ext Volt 0 = no, Ext Volt 1 = no, Ext Volt 2 = no, Ext Volt 3 = no
echo commands = yes
output format = raw HEX
serial sync mode disabled
```

8. Click Upload on the Toolbar to upload stored data in a form that Sea-Bird's data processing software can use. SEATERM responds as follows:
   A. SEATERM sends **OutputFormat=0** to set the output format to raw hexadecimal.
   B. SEATERM sends the status (**DS**), header (**DH**), and calibration coefficients (**DCal**) commands, displays the responses, and writes the commands and responses to the upload file. These commands provide you with information regarding the number of samples in memory, sample interval, headers, calibration coefficients, etc.
   C. **If you selected *By scan number range* in the Configuration Options dialog box (Configure menu)** – a dialog box requests the range. Enter the desired values, and click OK.
   D. **If you selected *Prompt for header information* in the Configuration Options dialog box (Configure menu)** – a dialog box with the header form appears. Enter the desired header information, and click OK. SEATERM writes the header information to the upload file.
   E. In the Open dialog box, enter the desired upload file name and click OK. The upload file has a .hex extension.
   F. SEATERM sends the data upload command (**DDb,e**).
   G. When the data has been uploaded, SEATERM shows the S> prompt.

9. Ensure all data has been uploaded from the 16*plus* by reviewing and processing the data:
   A. Use **SEASAVE** to display the *raw* hexadecimal data in engineering units (see *Verifying Contents of .con File* and SEASAVE manual / Help files).
   B. Use **SBE Data Processing** to process and plot the data (see *Processing Data Using SBE Data Processing* and SBE Data Processing manual / Help files).

Note:
To prepare for re-deployment:
1. After all data has been uploaded, send **InitLogging**. If this command is not sent and sampling is started, new data will be stored after the last recorded sample, preventing use of the entire memory capacity.
2. Send **QS** to put the 16*plus* in quiescent (sleep) state until ready to redeploy. The quiescent current is only 30 microamps, so the batteries can be left in place without significant loss of capacity.

Processing Data Using SBE Data Processing

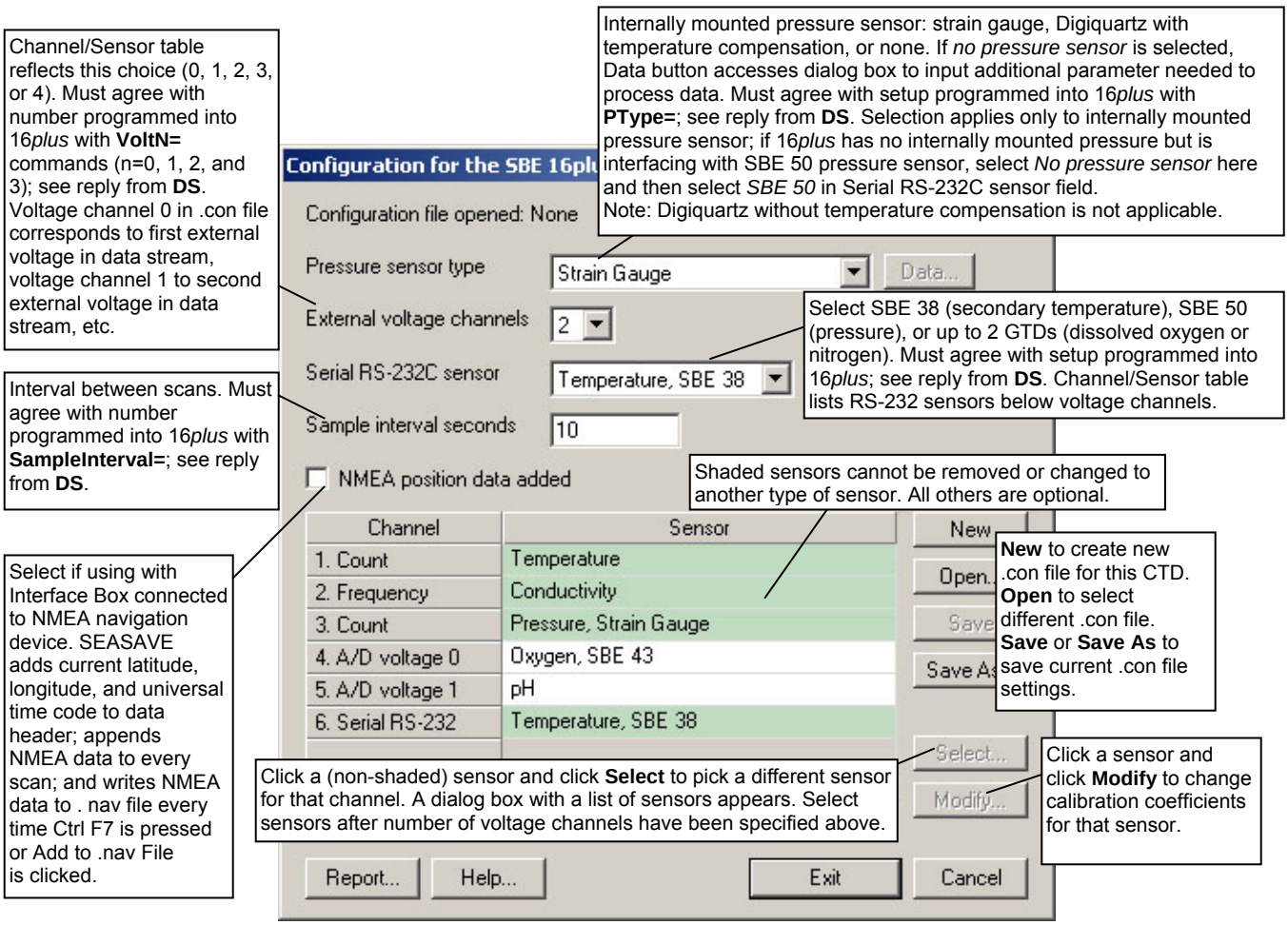
Notes:
- See the SBE Data Processing manual and/or Help files.
- When we ship a new instrument, we include a .con file that reflects the current instrument configuration *as we know it*. The .con file is named with the instrument serial number, followed with the .con extension. For example, for an instrument with serial number 2375, Sea-Bird names the .con file *2375.con*. You may rename the .con file if desired; this will not affect the results.
- In the 16*plus* setup commands, external voltage numbers 0, 1, 2, and 3 correspond to wiring of sensors to a voltage channel on the end cap (see *Dimensions and End Cap Connectors* in *Section 2: Description of SBE 16plus*). However, in the .con file, voltage 0 is the first external voltage in the data stream, voltage 1 is the second, etc.

1. Convert the .hex (raw data) file (uploaded from 16*plus* memory or real-time file from SEASAVE) to a .cnv (engineering units) file in SBE Data Processing's Data Conversion module.
2. Once the data is converted: perform further processing (filter, remove bad data, etc.), calculate derived variables, and plot data using SBE Data Processing's other modules.

Verifying Contents of Configuration (.con) File

To convert the .hex (raw data) file, you need a .con file, which defines the instrument – integrated sensors, and channels, serial numbers, and calibration dates and coefficients for all sensors (conductivity, temperature, and pressure as well as auxiliary sensors). SBE Data Processing uses the .con file information to interpret and process the raw data. **If the .con file does not match the actual instrument configuration, the software will be unable to interpret and process the data correctly.**

To view or modify the .con file:
1. Double click on SBEDataProc.exe.
2. In the Configure menu, select *SBE 16 Seacat plus CTD*. The configuration dialog box appears. In the configuration dialog box, click Open.
3. In the Open dialog box, select the appropriate .con file and click Open. Verify that the sensors match those on your 16*plus*, and that auxiliary sensors are assigned to the correct voltage channels. Verify that calibration coefficients for all sensors are up-to-date.



4. Click *Save* or *Save As* to save any changes to the .con file. Click Exit when done reviewing / modifying the .con file.

Editing Raw Data File

Sometimes users want to edit the raw .hex data file before beginning processing, to remove data at the beginning of the file corresponding to instrument *soak* time, to remove blocks of bad data, to edit the header, or to add explanatory notes about the cast. **Editing the raw .hex file can corrupt the data, making it impossible to perform further processing using Sea-Bird software.** Sea-Bird strongly recommends that you first convert the data to a .cnv file (using the Data Conversion module in SBE Data Processing), and then use other SBE Data Processing modules to edit the .cnv file as desired.

Note:
Although we provide this technique for editing a raw .hex file, **Sea-Bird's strong recommendation, as described above, is to always convert the raw data file and then edit the converted file.**

The procedure for editing a .hex data file described below has been found to work correctly on computers running Windows 98, 2000, and NT. **If the editing is not performed using this technique, SBE Data Processing may reject the edited data file and give you an error message.**

1. **Make a back-up copy of your .hex data file before you begin.**
2. Run **WordPad**.
3. In the File menu, select Open. The Open dialog box appears. For *Files of type*, select *All Documents (*.*)*. Browse to the desired .hex data file and click Open.
4. Edit the file as desired, **inserting any new header lines after the System Upload Time line**. Note that all header lines must begin with an asterisk (*), and *END* indicates the end of the header. An example is shown below (for an SBE 21), with the added lines in bold:

```
* Sea-Bird SBE 21 Data File:
* FileName = C:\Odis\SAT2-ODIS\oct14-19\oc15_99.hex
* Software Version Seasave Win32 v1.10
* Temperature SN = 2366
* Conductivity SN = 2366
* System UpLoad Time = Oct 15 1999  10:57:19
* Testing adding header lines
* Must start with an asterisk
* Place anywhere between System Upload Time & END of header
* NMEA Latitude = 30 59.70 N
* NMEA Longitude = 081 37.93 W
* NMEA UTC (Time) = Oct 15 1999  10:57:19
* Store Lat/Lon Data = Append to Every Scan and Append to .NAV
File When <Ctrl F7> is Pressed
** Ship:       Sea-Bird
** Cruise:     Sea-Bird Header Test
** Station:
** Latitude:
** Longitude:
*END*
```

5. In the File menu, select Save (**not** Save As). If you are running Windows 2000, the following message displays:

   ```
   You are about to save the document in a Text-Only format,
   which will remove all formatting. Are you sure you want to do
   this?
   ```

   Ignore the message and click *Yes*.
6. In the File menu, select Exit.

Section 5: Routine Maintenance and Calibration

This section reviews:
- corrosion precautions
- connector mating and maintenance
- battery replacement
- conductivity cell storage and cleaning
- pressure sensor maintenance
- pump maintenance
- AF24173 Anti-Foulant Device replacement
- sensor calibration

The accuracy of the SBE 16*plus* is sustained by the care and calibration of the sensors and by establishing proper handling practices.

Corrosion Precautions

Rinse the SBE 16*plus* with fresh water after use and prior to storage.

For both the plastic and titanium housing, all exposed metal is titanium (the plastic housing has a titanium end cap). No corrosion precautions are required, but direct electrical connection of the titanium to dissimilar metal hardware should be avoided.

Connector Mating and Maintenance

CAUTION:
Do not use WD-40 or other petroleum-based lubricants, as they will damage the connectors.

Mated connectors do not require periodic disassembly or other attention. Inspect connectors that are unmated for signs of corrosion product around the pins. When remating:

1. Lightly lubricate the inside of the dummy plug/cable connector with silicone grease (DC-4 or equivalent).
2. **Standard Connector** - Install the plug/cable connector, aligning the raised bump on the side of the plug/cable connector with the large pin (pin 1 - ground) on the 16*plus*. Remove any trapped air by *burping* or gently squeezing the plug/connector near the top and moving your fingers toward the end cap. **OR**
   MCBH Connector – Install the plug/cable connector, aligning the pins.
3. Place the locking sleeve over the plug/cable connector. Tighten the locking sleeve finger tight only. **Do not overtighten the locking sleeve and do not use a wrench or pliers.**

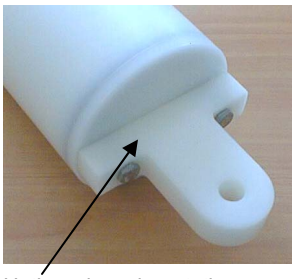
Verify that a cable or dummy plug is installed for each connector on the system before deployment.

Replacing Alkaline Batteries

Alkaline D-cell
(MN1300, LR20)

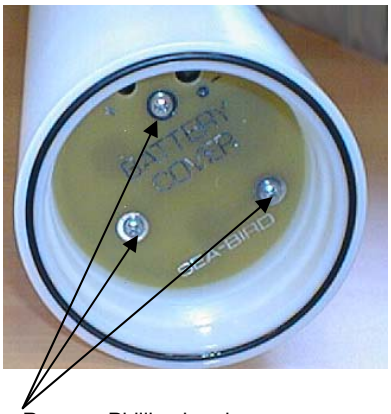
The SBE 16*plus* uses alkaline D-cells (Duracell MN1300, LR20), dropped into the battery compartment.

Leave the batteries in place when storing the SBE 16*plus* to prevent depletion of the back-up lithium batteries by the real-time clock. Even *exhausted* main batteries will power the clock (30 microamperes) almost indefinitely. If the 16*plus* is to be stored for long periods, leave the batteries in place and replace them yearly.



Unthread cap by rotating
counter-clockwise

1. Remove the battery end cap (end cap without connectors):
   A. Wipe the outside of the end cap and housing dry, being careful to remove any water at the seam between them.
   B. Unthread the end cap by rotating counter-clockwise (use a wrench on the white plastic bar if necessary).
   C. Remove any water from the O-ring mating surfaces inside the housing with a lint-free cloth or tissue.
   D. Put the end cap aside, being careful to protect the O-ring from damage or contamination.



Remove Phillips-head
screws and washers

2. Remove the battery cover plate from the housing:
   A. Remove the three Phillips-head screws and washers from the battery cover plate inside the housing.
   B. The battery cover plate will pop out. Put it aside.

3. Turn the 16*plus* over and remove the batteries.

4. Install the new batteries, with the + terminals against the flat battery contacts and the - terminals against the spring contacts.

5. Reinstall the battery cover plate in the housing:
   A. Align the battery cover plate with the housing. The posts inside the housing are not placed symmetrically, so the cover plate fits into the housing only one way. Looking at the cover plate, note that one screw hole is closer to the edge than the others, corresponding to the post that is closest to the housing.
   B. Reinstall the three Phillips-head screws and washers, while pushing hard on the battery cover plate to depress the spring contacts at the bottom of the battery compartment. **The screws must be fully tightened, or battery power to the circuitry will be intermittent**.

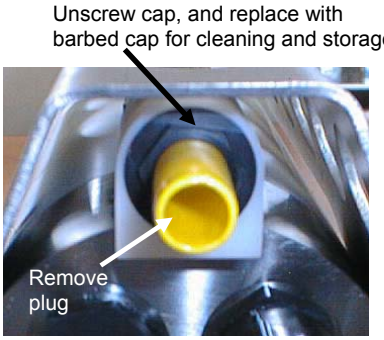
6. Check the battery voltage at BAT + and BAT - on the battery cover plate. It should be approximately 13.5 volts.

7. Reinstall the battery end cap:
   A. Remove any water from the O-rings and mating surfaces with a lint-free cloth or tissue. Inspect the O-rings and mating surfaces for dirt, nicks, and cuts. Clean or replace as necessary. Apply a light coat of o-ring lubricant (Parker Super O Lube) to O-rings and mating surfaces.
   B. Carefully fit the end cap into the housing and rethread the end cap into place. Use a wrench on the white plastic bar to ensure the end cap is tightly secured.

Conductivity Cell Maintenance

CAUTIONS:

- **Do not put a brush or any object inside the conductivity cell to dry it or clean it.** Touching and bending the electrodes can change the calibration. Large bends and movement of the electrodes can damage the cell.
- **Do not store the 16*plus* with water in the conductivity cell.** Freezing temperatures (for example, in Arctic environments or during air shipment) can break the cell if it is full of water.



The SBE 16*plus'* conductivity cell is shipped dry to prevent freezing in shipping. **Refer to *Application Note 2D: Instructions for Care and Cleaning of Conductivity Cells* for conductivity cell cleaning procedures and cleaning materials.**

- The Active Use (after each cast) section of the application note is not applicable to the 16*plus*, which is intended for use as a moored instrument.

The 16*plus* is shipped with a kit for cell filling and storage. The kit includes a syringe and tubing assembly, and two anti-foulant device caps with hose barbs. The tubing cannot attach to an anti-foulant device cap that is not barbed.

- If your 16*plus* does not include a pump - the installed anti-foulant device caps at both ends of the conductivity cell are not barbed.
- If your 16*plus* includes a pump - the installed anti-foulant device cap at the pump end of the cell is barbed; the installed anti-foulant device cap at the intake end of the cell is not barbed.

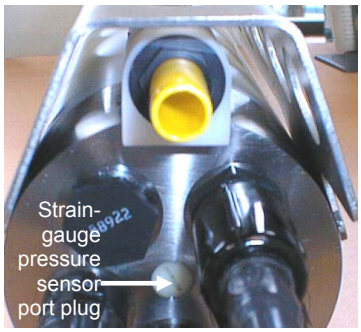
Cleaning and storage instructions require use of the syringe and tubing assembly at the intake end of the cell (requiring one barbed cap), and looping Tygon tubing from end to end of the cell (requiring two barbed caps). Remove the installed anti-foulant device cap(s) and replace them with the anti-foulant device cap(s) with hose barbs **for cleaning and storage only**. Remember to reinstall the original anti-foulant device cap(s) before deployment. **Deploying a 16*plus* with barbed anti-foulant device cap(s) in place of the installed caps is likely to produce undesirable results in your data.** See *Replacing Anti-Foulant Devices* for safety precautions when handling the AF24173 Anti-Foulant Devices.

Internally Mounted Pressure Sensor (optional) Maintenance

CAUTION:
Do not put a brush or any object in the pressure port. Doing so may damage or break the pressure sensor.

Pressure sensor maintenance varies, depending on the type of pressure sensor in your SBE 16*plus*.

Strain Gauge Pressure Sensor



The pressure port plug has a small vent hole to allow hydrostatic pressure to be transmitted to the pressure sensor inside the instrument, while providing protection for the pressure sensor, keeping most particles and debris out of the pressure port.

Periodically (approximately once a year) inspect the pressure port to remove any particles, debris, etc:

1. Unscrew the pressure port plug from the pressure port.
2. Rinse the pressure port with warm, de-ionized water to remove any particles, debris, etc.
3. Replace the pressure port plug.

Quartz Pressure Sensor

Nylon pressure capillary fitting for 16*plus* with Quartz pressure sensor

At the factory, the pressure sensor and pressure port were filled with a silicon oil, and a nylon pressure capillary fitting – which includes a pressure port fitting and an external capillary tube – were used to retain the oil. The oil transmits hydrostatic pressure via internal, stainless steel, capillary tubing to the pressure sensor inside the instrument, and prevents corrosion that might occur if the sensor diaphragm was exposed to water. The internal tubing and nylon capillary fitting are vacuum back-filled at the factory.

Because of the viscosity of the silicone oil and capillary action, the silicone oil does not run out of the external capillary tube. However, due to temperature and pressure cycling over long periods, it is normal for some oil to slowly leak out of the external capillary tube. **When the oil is not visible or is receding inside the translucent tube, or if the fitting has been damaged, refill the oil** using the supplied pressure sensor oil refill kit. See *Application Note 12-1: Pressure Port Oil Refill Procedure & Nylon Capillary Fitting Replacement*.

Pump (optional) Maintenance

See *Application Note 75: Maintenance of SBE 5T, 5P, and 5M Pumps*.

Replacing Anti-Foulant Devices (SBE 16*plus*, SBE 19*plus*)

AF24173
Anti-Foulant
Device

The SBE 16*plus* and 19*plus* (moored option) have an anti-foulant device cup and cap on each end of the conductivity cell. A new SBE 16*plus* (or moored option 19*plus*) is shipped with an Anti-Foulant Device and a protective plug pre-installed in each cup.

WARNING!

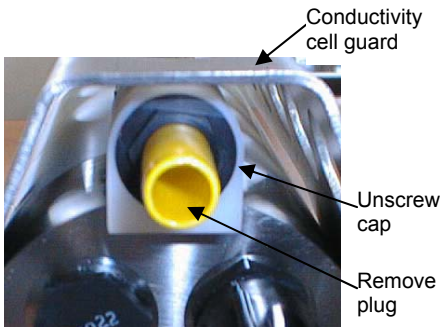
AF24173 Anti-Foulant Devices contain bis(tributyltin) oxide. Handle the devices only with rubber or latex gloves. Wear eye protection. Wash with soap and water after handling.

Read precautionary information on product label (see Appendix V) before proceeding.

It is a violation of US Federal Law to use this product in a manner inconsistent with its labeling.

Wearing rubber or latex gloves, follow this procedure to replace each Anti-Foulant Device (two):

1. Remove the protective plug;
2. Unscrew the cap with a 5/8-inch socket wrench;
3. Remove the old Anti-Foulant Device. If the old Anti-Foulant Device is difficult to remove:
   - Use needle-nose pliers and carefully break up material;
   - If necessary, remove the conductivity cell guard to provide easier access;
4. Place the new Anti-Foulant Device in the cup;
5. Rethread the cap onto the cup. Do not over tighten;
6. Replace the protective plug if not ready to redeploy.



CAUTION:

One of the anti-foulant device cups is attached to the guard and connected to the conductivity cell. **Removing the guard without disconnecting the cup from the guard will break the cell.** If the guard must be removed:

1. Remove the two screws connecting the anti-foulant device cup to the guard;
2. Remove the four Phillips-head screws connecting the guard to the housing and sensor end cap;
3. Gently lift the guard away.

Sensor Calibration

Sea-Bird sensors are calibrated by subjecting them to known physical conditions and measuring the sensor responses. Coefficients are then computed, which may be used with appropriate algorithms to obtain engineering units. The conductivity, temperature, and (optional) internally mounted pressure sensor on the SBE 16*plus* are supplied fully calibrated, with coefficients stored in EEPROM in the 16*plus* and printed on their respective Calibration Certificates.

We recommend that the SBE 16*plus* be returned to Sea-Bird for calibration.

Note
After recalibration, Sea-Bird enters the new calibration coefficients in the 16*plus* EEPROM, and ships the instrument back to the user with Calibration Certificates showing the new coefficients. The user must enter the coefficients in the instrument configuration (.con) file in the Configure menu in SEASAVE or SBE Data Processing.

Conductivity Sensor

The conductivity sensor incorporates a fixed precision resistor in parallel with the cell. When the cell is dry and in air, the sensor's electrical circuitry outputs a frequency representative of the fixed resistor. This frequency is recorded on the Calibration Certificate and should remain stable (within 1 Hz) over time.

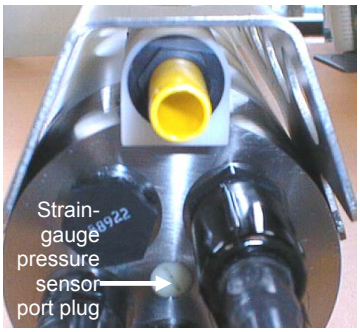
The primary mechanism for calibration drift in conductivity sensors is the fouling of the cell by chemical or biological deposits. Fouling changes the cell geometry, resulting in a shift in cell constant.

Accordingly, the most important determinant of long-term sensor accuracy is the cleanliness of the cell. We recommend that the conductivity sensors be calibrated before and after deployment, but particularly when the cell has been exposed to contamination by oil slicks or biological material.

Temperature Sensor

The primary source of temperature sensor calibration drift is the aging of the thermistor element. Sensor drift will usually be a few thousandths of a degree during the first year, and less in subsequent intervals. Sensor drift is not substantially dependent upon the environmental conditions of use, and — unlike platinum or copper elements — the thermistor is insensitive to shock.

Internally Mounted Pressure Sensor



The SBE 16*plus* is available with an internally mounted strain-gauge or Quartz pressure sensor. These sensors are capable of meeting the 16*plus* error specification with some allowance for aging and ambient-temperature induced drift.

Pressure sensors show most of their error as a linear offset from zero. A technique is provided below for making small corrections to the pressure sensor calibration using the *offset* (**POffset=**) calibration coefficient term by comparing SBE 16*plus* pressure output to readings from a barometer.

Allow the SBE 16*plus* to equilibrate in a reasonably constant temperature environment for at least 5 hours before starting. Pressure sensors exhibit a transient change in their output in response to changes in their environmental temperature. Sea-Bird instruments are constructed to minimize this by thermally decoupling the sensor from the body of the instrument. However, there is still some residual effect; allowing the 16*plus* to equilibrate before starting will provide the most accurate calibration correction.

Note:
The internally mounted pressure sensor is an absolute sensor, so its **raw** output includes the effect of atmospheric pressure (14.7 psi). As shown on the Calibration Sheet, Sea-Bird's calibration (and resulting calibration coefficients) is in terms of psia. However, when outputting pressure in **engineering units**, the 16*plus* outputs pressure relative to the ocean surface (i.e., at the surface the output pressure is 0 decibars). The 16*plus* uses the following equation to convert psia to decibars:
pressure (db) =
[pressure (psia) - 14.7] * 0.689476

1. Place the 16*plus* in the orientation it will have when deployed.

2. In SEATERM:
   A. Set the pressure offset to 0.0 (**POffset=0**).
   B. Send **TP** to measure the 16*plus* pressure 100 times and transmit converted data in engineering units (decibars).

3. Compare the 16*plus* output to the reading from a good barometer at the same elevation as the 16*plus* pressure sensor.
   Calculate *offset* = barometer reading – 16*plus* reading

4. Enter the calculated offset (positive or negative) in two places:
   - In the 16*plus* EEPROM, using **POffset=** in SEATERM, **and**
   - In the configuration (.con) file, using SEASAVE or SBE Data Processing.

Offset Correction Example
Absolute pressure measured by a barometer is 1010.50 mbar. Pressure displayed from 16*plus* is -2.5 dbars.
Convert barometer reading to dbars using the relationship: mbar * 0.01 = dbar
Barometer reading = 1010.50 mbar * 0.01 = 10.1050 dbar
The 16*plus*' internal calculations and our processing software output gage pressure, using an assumed value of 14.7 psi for atmospheric pressure. Convert 16*plus* reading from gage to absolute by adding 14.7 psia to the 16*plus* output:
-2.5 dbars + (14.7 psi * 0.689476 dbar/psia) = -2.5 + 10.13 = 7.635 dbars
Offset = 10.1050 – 7.635 = + 2.47 dbars
Enter offset in 16*plus* and in .con file.

For demanding applications, or where the sensor's air ambient pressure response has changed significantly, calibration using a dead-weight generator is recommended. The end cap's $^{7}/_{16}$-20 straight thread permits mechanical connection to the pressure source. Use a fitting that has an O-ring tapered seal, such as Swagelok-200-1-4ST, which conforms to MS16142 boss.

Section 6: Troubleshooting

This section reviews common problems in operating the SBE 16*plus*, and provides the most common causes and solutions.

Problem 1: Unable to Communicate with SBE 16*plus*

The S> prompt indicates that communications between the SBE 16*plus* and computer have been established. Before proceeding with troubleshooting, attempt to establish communications again by clicking Connect on SEATERM's toolbar or pressing the Enter key several times.

Cause/Solution 1: The I/O cable connection may be loose. Check the cabling between the 16*plus* and computer for a loose connection.

Cause/Solution 2: The instrument type and/or its communication settings may not have been entered correctly in SEATERM. Select the *SBE 16plus* in the Configure menu and verify the settings in the Configuration Options dialog box. The settings should match those on the instrument Configuration Sheet.

Cause/Solution 3: The I/O cable may not be the correct one. The I/O cable supplied with the 16*plus* permits connection to standard 9-pin RS-232 interfaces. See *Dimensions and End Cap Connectors* in *Section 2: Description of SBE 16plus* for cable pinouts.

Problem 2: No Data Recorded

Cause/Solution 1: The memory may be full; once the memory is full, no further data will be recorded. Verify that the memory is not full using **DS** (*free = 0* or *1* if memory is full). Sea-Bird recommends that you upload all previous data before beginning another deployment. Once the data is uploaded, send **InitLogging** to reset the memory. After the memory is reset, **DS** will show *samples = 0*.

Problem 3: Nonsense or Unreasonable Data

The symptom of this problem is a data file that contains nonsense values (for example, 9999.999) or unreasonable values (for example, values that are outside the expected range of the data).

Cause/Solution 1: A data file with nonsense values may be caused by incorrect instrument configuration:

- Bad data may be caused by incorrect configuration in the 16*plus*. Send **DS** to verify the 16*plus* setup matches the instrument Configuration Sheet (correct internally mounted pressure sensor, voltage sensors assigned to correct channels, etc).
- Bad data may be caused by incorrect configuration in the instrument .con file. Verify the settings in the instrument .con file match the instrument Configuration Sheet.

Note:
Each 16*plus* is shipped with a configuration (.con) file that matches the configuration of the instrument (number and type of auxiliary sensors, etc.) and includes the instrument calibration coefficients.

Cause/Solution 2: A data file with unreasonable (i.e., out of the expected range) values for temperature, conductivity, etc. may be caused by incorrect calibration coefficients:

- If you uploaded data in engineering units (**OutputFormat=1**, **3**, **4**, or **5**) – Bad data may be caused by incorrect calibration coefficients in the 16*plus*. Send **DCal** to verify the calibration coefficients in the 16*plus* match the instrument Calibration Certificates. Note that calibration coefficients do not affect the raw data stored in 16*plus* memory. If you have not yet overwritten the memory with new data, you can correct the coefficients and then upload the data again.
- If you are viewing real-time data in SEASAVE or uploaded data in raw hexadecimal (**OutputFormat=0**) and are processing the data in SEASAVE or SBE Data Processing - Bad data may be caused by incorrect calibration coefficients in the instrument .con file. Verify the calibration coefficients in the .con file match the instrument Calibration Certificates.
- For RS-232 sensors interfacing to the 16*plus*: Bad data may be caused by incorrect calibration coefficients programmed into the instrument. Connect the instrument directly to the computer to verify the calibration coefficients match the instrument Calibration Certificate.

Problem 4: Program Corrupted

Cause/Solution 1: In rare cases, the program that controls the 16*plus* microprocessor can be corrupted by a severe static shock or other problem. This program can be initialized by using the reset switch. Proceed as follows to initialize:

1. Open the battery end cap and remove the batteries (see *Replacing Batteries* in *Section 5: Routine Maintenance and Calibration*).
2. There is a small, pushbutton switch on the battery compartment bulkhead, which is visible after the batteries are removed. The switch is used to disconnect the internal back-up lithium batteries from the electronics. Push the switch in for 1 second.
3. Reinstall or replace the batteries, and close the battery end cap.
4. Establish communications with the 16*plus* (see *Section 3: Power and Communications Test*). Send **DS** to verify that the date and time and sample number are correct.

Note:
Using the reset switch does not affect the 16*plus* memory - data in memory and user-programmable parameter values are unaffected.

Glossary

Battery pack – Nine alkaline D-cells (Duracell MN1300, LR20) standard.

Fouling – Biological growth in the conductivity cell during deployment.

PCB – Printed Circuit Board.

SBE Data Processing – Sea-Bird's Win 2000/XP data processing software, which calculates and plots temperature, conductivity, and optional internally mounted pressure, data from auxiliary sensors, and derived variables such as salinity and sound velocity.

Scan – One data sample containing temperature, conductivity, optional internally mounted pressure, date and time, and optional auxiliary inputs.

SEACAT – High-accuracy conductivity, temperature, and pressure recorder. The SEACAT is available as the SBE 16*plus* (moored applications) and SBE 19*plus* (moored or profiling applications). A *plus* version of the SBE 21 (thermosalinograph) is under development.
The 16*plus* is available in three versions:

- 16*plus* with **RS-232** interface (this manual)
- 16*plus* with **RS-485** interface
- 16*plus*-IM with **inductive modem** interface

SEASAVE V7 – Sea-Bird's Win 2000/XP software used to acquire, convert, and display real-time or archived raw data.

SEASOFT-Win32– Sea-Bird's complete Win 2000/XP software package, which includes software for communication, real-time data acquisition, and data analysis and display. SEASOFT-Win32 includes ***SEATERM***, ***SEASAVE* V7**, ***SBE Data Processing***.

SEATERM – Sea-Bird's Win 95/98/NT/2000/XP terminal program used to communicate with the SBE 16*plus*.

TCXO – Temperature Compensated Crystal Oscillator.

Triton X-100 – Reagent grade non-ionic surfactant (detergent), used for cleaning the conductivity cell. Triton can be ordered from Sea-Bird, but should also be available locally from chemical supply or laboratory products companies. Triton is manufactured by Mallinkrodt Baker; see http://www.mallbaker.com/changecountry.asp?back=/Default.asp for local distributors.

Appendix I: Functional Description and Circuitry

Sensors

The SBE16*plus* embodies the same sensor elements (3-electrode, 2-terminal, borosilicate glass cell, and pressure-protected thermistor) previously employed in Sea-Bird's modular SBE 3 and SBE 4 sensors and in the original SEACAT design. The SBE 16*plus* differs from the SBE 16 in that it uses three independent channels to digitize temperature, conductivity, and internally mounted pressure concurrently. Multiplexing is not used for these channels.

The optional internally mounted pressure sensor is a Druck strain-gauge sensor or a Quartz pressure sensor.

Sensor Interface

Temperature is acquired by applying an AC excitation to a bridge circuit containing an ultra-stable aged thermistor with a drift rate of less than 0.002 ºC per year. The other elements in the bridge are VISHAY precision resistors. A 24-bit A/D converter digitizes the output of the bridge. AC excitation and ratiometric comparison avoids errors caused by parasitic thermocouples, offset voltages, leakage currents, and reference errors.

Conductivity is acquired using an ultra-precision Wein-Bridge oscillator to generate a frequency output in response to changes in conductivity.

Internally mounted strain-gauge pressure is acquired by applying an AC excitation to the pressure bridge. A 24-bit A/D converter digitizes the output of the bridge. AC excitation and ratiometric comparison avoids errors caused by parasitic thermocouples, offset voltages, leakage currents, and reference errors. A silicon diode embedded in the pressure bridge is used to measure the temperature of the pressure bridge. This temperature is used to perform offset and span corrections on the measured pressure signal.

The four external 0 to 5 volt DC voltage channels are processed by differential amplifiers with an input resistance of 50K ohms and are digitized with a 14-bit A/D converter.

Real-Time Clock

To minimize power and improve clock accuracy, a temperature-compensated crystal oscillator (TCXO) is used as the real-time-clock frequency source. The TCXO is accurate to ± 1 minute per year (0 ºC to 40 ºC).

Battery Wiring

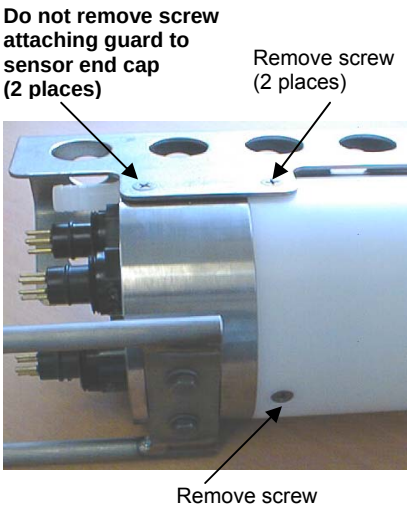
SBE 16*plus* main battery is a series connection of D-cells that drop into the battery compartment as a cluster of end-to-end stacks, three batteries each (standard 9-cell battery pack has three stacks). The positive battery connections are contact areas on double-thick printed circuit disks that form the internal bulkhead and battery retainer plates. Battery negative contacts are heavy beryllium-copper springs. The three cell stacks are aligned by plastic insulated aluminum spacers which also serve as electrical interconnects. The battery-to-circuit card connection is made by means of a Molex-type 3-pin pc board connector (JP3 on the power PCB).

The Power PCB contains three series-connected Panasonic BR-2/3A lithium cells (non-hazardous) which are diode OR'd with the main battery (and external power source, if used). The back-up lithium supply is capable of maintaining the buffer and the real-time clock if the main batteries and/or external power is removed. If the back-up lithium battery voltage (*Vlith* in the **DS** response) falls below 7 volts, replace the back-up batteries.

Appendix II: Electronics Disassembly/Reassembly

CAUTION:
Use caution during disassembly and reassembly to avoid breaking the conductivity cell.

Disassembly



1. **As a precaution, upload any data in memory before beginning.**

2. Remove the two Phillips-head screws holding the conductivity cell guard to the housing. **Do not remove the two screws holding the conductivity cell guard to the sensor end cap.**

3. Remove the Phillips-head screw holding the sensor end cap to the housing on the side opposite the conductivity cell guard.

4. Remove the sensor end cap (with attached conductivity cell and cell guard) and electronics:
   A. Wipe the outside of the sensor end cap and housing dry, being careful to remove any water at the seam between them.
   B. Slide the end cap and attached electronics out of the housing.
   C. The electronics are electrically connected to the battery compartment bulkhead with a Molex connector. Disconnect the Molex connector.
   D. Remove any water from the O-rings and mating surfaces inside the housing with a lint-free cloth or tissue.
   E. Be careful to protect the O-rings from damage or contamination.

Reassembly

Note:
Before delivery, a desiccant package is placed in the electronics chamber, and the electronics chamber is filled with dry Argon gas. These measures help prevent condensation.
If the electronics are exposed to the atmosphere, dry gas backfill with Argon and replace the desiccant package.
See *Application Note 71: Desiccant Use and Regeneration (drying)* for desiccant information.
Battery replacement does not affect desiccation of the electronics, as no significant gas exchange is possible unless the electronics PCBs are actually removed from the housing.

1. Reinstall the sensor end cap, conductivity cell and guard, and electronics:
   A. Remove any water from the O-rings and mating surfaces in the housing with a lint-free cloth or tissue. Inspect the O-rings and mating surfaces for dirt, nicks, and cuts. Clean or replace as necessary. Apply a light coat of O-ring lubricant (Parker Super O Lube) to the O-rings and mating surfaces.
   B. Plug the Molex connector onto the pins on the battery compartment bulkhead. Verify the connector holes and pins are properly aligned.
   C. Carefully fit the end cap and electronics into the housing until the O-rings are fully seated.

2. Reinstall the three screws to secure the end cap.

3. Reset the date and time (**MMDDYY=** and **HHMMSS=**) and initialize logging (**InitLogging**) before redeploying. No other parameters should have been affected by electronics disassembly (send **DS** to verify).

Appendix III: Command Summary

CATEGORY	COMMAND	DESCRIPTION
Status	**DS**	Display status and setup parameters.
General Setup	**MMDDYY=mmddyy**	Set real-time clock month, day, year. Follow with **HHMMSS=** or it will not set date.
	DDMMYY=ddmmyy	Set real-time clock day, month, year. Follow with **HHMMSS=** or it will not set date.
	HHMMSS=hhmmss	Set real-time clock hour, minute, second.
	Baud=x	**x=** baud rate (1200, 2400, 4800, 9600, 19200, or 38400). Default 9600.
	Echo=x	**x=Y**: Echo characters as you type. **x=N**: Do not echo characters.
	TxRealTime=x	**x=Y**: Output real-time data. **x=N**: Do not output real-time data.
	PumpMode=x	**x=0**: No pump. **x=1**: Run pump for 0.5 seconds before each sample. **x=2**: Run pump during each sample.
	NCycles=x	**x=** number of measurements to take and average for each sample. Default = 1.
	InitLogging	After all previous data uploaded, send this command before starting to sample to make entire memory available for recording. If not sent, data stored after last sample. Equivalent to **SampleNumber=0**.
	SampleNumber=x	**x=** sample number for first sample when sampling begins. After all previous data uploaded, set to 0 before starting to sample to make entire memory available for recording. If not reset to 0, data stored after last sample. Equivalent to **InitLogging**.
	HeaderNumber=x	**x=** header number for first header when logging begins.
	FlashInit	Map bad blocks and erase FLASH memory, **which destroys all data in 16*plus***.
	QS	Enter quiescent (sleep) state. Main power turned off, but data logging and memory retention unaffected.
Output Format	**OutputFormat=x**	**x=0**: output raw frequencies and voltages in Hex. **x=1**: output converted data in Hex. **x=2**: output raw frequencies and voltages in decimal. **x=3**: output converted data in decimal. **x=4**: output converted data in decimal, in XML. **x=5**: output converted data in decimal, in XML, modified format.
	OutputSal=x	**x=Y**: Calculate and output salinity (psu). Only applies if **OutputFormat=3**, **4**, or **5**. **x=N**: Do not.
	OutputSV=x	**x=Y**: Calculate and output sound velocity (m/sec). Only applies if **OutputFormat=3**, **4**, or **5**. **x=N**: Do not.
	OutputUCSD=x	**x=Y**: Calculate and output density sigma-t (kg/m^3), battery voltage, and operating current (mA) with data polled while logging. Only applies if **OutputFormat=3**, **4**, or **5**. **x=N**: Do not.
Pressure Sensor Setup	**PType=x**	**Internally mounted pressure sensor type -** **x=0**: No internally mounted pressure sensor. **x=1**: Strain gauge. **x=3**: Quartz with temperature compensation.
	RefPress=x	**x=** reference pressure (gauge) in db to use if 16*plus* does not include internally mounted pressure sensor.
	ParosIntegration=x	**x=** integration time (seconds) for optional internally mounted Quartz pressure sensor (1 - 600 seconds; default = 1).

CATEGORY	COMMAND	DESCRIPTION
Voltage Sensor Setup	**Volt0=x**	**x=Y**: Enable external voltage 0. **x=N**: Do not.
	Volt1=x	**x=Y**: Enable external voltage 1. **x=N**: Do not.
	Volt2=x	**x=Y**: Enable external voltage 2. **x=N**: Do not.
	Volt3=x	**x=Y**: Enable external voltage 3. **x=N**: Do not.
	DelayBeforeSampling =x	**x=** time (seconds) to wait after switching on external voltage before sampling (0-32,000 seconds). Default 0 seconds.
	Biowiper=x	**x=Y**: Configuration includes ECO-FL fluorometer with Bio-Wiper. **x=N** (default): Does not.
RS-232 Sensor Setup	**SBE38=x**	**x=Y**: Enable SBE 38. **x=N**: Do not.
	SBE50=x	**x=Y**: Enable SBE 50. **x=N**: Do not.
	GTD=x	**x=Y**: Enable GTD. **x=N**: Do not.
	DualGTD=x	**x=Y**: Enable dual (2) GTDs. **x=N**: Do not.
	TGTD	Measure GTD(s), output 1 converted data sample for each GTD.
	SendGTD=command	Command 16*plus* to send **command** to GTD and receive response (**command** can be any command recognized by GTD).
Autonomous Sampling (logging)	**SampleInterval=x**	**x=** interval (seconds) between samples (10 - 14,400).
	StartNow	Start autonomous sampling now.
	StartMMDDYY =mmddyy	Delayed start: month, day, year. Must follow with **StartHHMMSS=**.
	StartDDMMYY =ddmmyy	Delayed start: day, month, year. Must follow with **StartHHMMSS=.**
	StartHHMMSS =hhmmss	Delayed start: hour, minute, second.
	StartLater	Start autonomous sampling at delayed start date and time.
	Stop	Stop autonomous sampling or stop waiting to start autonomous sampling. Press Enter key to get S> prompt before entering **Stop**. Must stop sampling before uploading data.
Polled Sampling	**SL**	Output last sample from buffer and leave power on.
	SLT	Output last sample from buffer, then take new sample and store data in buffer. Leave power on.
	TS	Take sample, store data in buffer, output data, and leave power on.
	TSS	Take sample, **store in buffer and FLASH memory**, output data, and turn power off.
	TSSOn	Take sample, **store in buffer and FLASH memory**, output data, and leave power on.
Serial Line Sync	**SyncMode=x**	**x=Y**: enable serial line sync mode. When RS-232 RX line is high (3-10 VDC) for 1-1000 milliseconds, 16*plus* takes a sample, stores data in FLASH memory, and (if **TxRealTime=Y**) transmits real-time data. **x=N**: disable serial line sync mode.
	SyncWait=x	**x=** time (seconds) 16*plus* monitors RS-232 line for commands after executing take sample command. Range 0 - 120 seconds; default 0 seconds.
Data Upload	**DDb,e**	Upload data from scan **b** to scan **e**. Stop autonomous sampling before sending **DDB,e**.
	DHb,e	Upload headers from header **b** to header **e**.

Note:
Use Upload on the Toolbar or Upload Data in the Data menu to upload data that will be processed by SBE Data Processing. Manually entering the data upload command does not produce data with the required header information for processing by SBE Data Processing.

CATEGORY	COMMAND	DESCRIPTION
Testing Takes and outputs 100 samples for each test (except as noted). Press Esc key or Stop on Toolbar to stop test.	**TT**	Measure temperature, output converted data.
	TC	Measure conductivity, output converted data.
	TP	Measure internally mounted pressure, output converted data.
	TV	Measure 4 external voltage channels, output converted data.
	TF	Measure frequency (internally mounted Quartz pressure sensor), output converted data.
	T38	Measure SBE 38, output converted data.
	T50	Measure SBE 50 pressure, output converted data.
	TTR	Measure temperature, output raw data
	TCR	Measure conductivity, output raw data.
	TPR	Measure internally mounted pressure, output raw data.
	TVR	Measure main battery voltage, lithium battery voltage, external current, pressure temperature, and 4 external voltage channels, output raw data.
	TFR	Measure frequency (internally mounted Quartz pressure sensor), output raw data.
	PumpOn	Turn pump on for testing purposes.
	PumpOff	Turn pump off for testing purposes.
Coefficients (F=floating point number; S=string with no spaces) Dates shown are when calibrations were performed. Calibration coefficients are initially factory-set and should agree with Calibration Certificates shipped with 16*plus*. Pressure sensor coefficients are for internally mounted pressure sensor.	**DCal**	Display calibration coefficients; all coefficients and dates listed below are included in display (as applicable). Use individual commands below to modify a particular coefficient or date.
	TCalDate=S	**S=**Temperature calibration date.
	TAO=F	**F=**Temperature A0.
	TA1=F	**F=**Temperature A1.
	TA2=F	**F=**Temperature A2.
	TA3=F	**F=**Temperature A3.
	TOffset=F	**F=**Temperature offset correction.
	CCalDate=S	**S=**Conductivity calibration date.
	CG=F	**F=**Conductivity G.
	CH=F	**F=**Conductivity H.
	CI=F	**F=**Conductivity I.
	CJ=F	**F=**Conductivity J.
	CPCOR=F	**F=**Conductivity pcor.
	CTCOR=F	**F=**Conductivity tcor.
	CSlope=F	**F=**Conductivity slope correction.
	PCalDate=S	**S=**Pressure calibration date.
	PRange=F	**F=**Pressure sensor full scale range (psi).
	POffset=F	**F=**Pressure offset correction.
	PA0=F	**F=**Strain gauge pressure A0.
	PA1=F	**F=**Strain gauge pressure A1.
	PA2=F	**F=**Strain gauge pressure A2.
	PTempA0=F	**F=**Strain gauge pressure temperature A0.
	PTempA1=F	**F=**Strain gauge pressure temperature A1.
	PTempA2=F	**F=**Strain gauge pressure temperature A2.
	PTCA0=F	**F=**Strain gauge pressure temperature compensation ptca0.
	PTCA1=F	**F=**Strain gauge pressure temperature compensation ptca1.
	PTCA2=F	**F=**Strain gauge pressure temperature compensation ptca2.
	PTCB0=F	**F=**Strain gauge pressure temperature compensation ptcb0.
	PTCB1=F	**F=**Strain gauge pressure temperature compensation ptcb1.
	PTCB2=F	**F=**Strain gauge pressure temperature compensation ptcb2.
	PC1=F	**F=**Quartz pressure C1.
	PC2=F	**F=**Quartz pressure C2.
	PC3=F	**F=**Quartz pressure C3.
	PD1=F	**F=**Quartz pressure D1.
	PD2=F	**F=**Quartz pressure D2.
	PT1=F	**F=**Quartz pressure T1.
	PT2=F	**F=**Quartz pressure T2.
	PT3=F	**F=**Quartz pressure T3.
	PT4=F	**F=**Quartz pressure T4.
	PSlope=F	**F=**Quartz pressure slope correction.
	ExtFreqSF=F	**F=**External frequency (internally mounted Quartz pressure sensor) scale factor.

Appendix IV: AF24173 Anti-Foulant Device

AF24173 Anti-Foulant Devices supplied for user replacement are supplied in polyethylene bags displaying the following label:

AF24173 ANTI-FOULANT DEVICE

FOR USE ONLY IN SEA-BIRD ELECTRONICS' CONDUCTIVITY SENSORS TO CONTROL THE GROWTH OF AQUATIC ORGANISMS WITHIN ELECTRONIC CONDUCTIVITY SENSORS.

ACTIVE INGREDIENT:

Bis(tributyltin) oxide……..……....	53.0%
OTHER INGREDIENTS: …….....	47.0%
Total…….....	100.0%

DANGER

See the complete label within the Conductivity Instrument Manual for Additional Precautionary Statements and Information on the Handling, Storage, and Disposal of this Product.

Net Contents: Two anti-foulant devices

Sea-Bird Electronics, Inc.
1808 - 136th Place Northeast
Bellevue, WA 98005

EPA Registration No. 74489-1
EPA Establishment No. 74489-WA-1

AF24173 Anti-Foulant Device

FOR USE ONLY IN SEA-BIRD ELECTRONICS' CONDUCTIVITY SENSORS TO CONTROL THE GROWTH OF AQUATIC ORGANISMS WITHIN ELECTRONIC CONDUCTIVITY SENSORS.

ACTIVE INGREDIENT:

Bis(tributyltin) oxide…….…….....	53.0%
OTHER INGREDIENTS: …….....	47.0%
Total…….....	100.0%

DANGER
See Precautionary Statements for additional information.

FIRST AID	
If on skin or clothing	• Take off contaminated clothing. • Rinse skin immediately with plenty of water for15-20 minutes. • Call a poison control center or doctor for treatment advice.
If swallowed	• Call poison control center or doctor immediately for treatment advice. • Have person drink several glasses of water. • Do not induce vomiting. • Do not give anything by mouth to an unconscious person.
If in eyes	• Hold eye open and rinse slowly and gently with water for 15-20 minutes. • Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. • Call a poison control center or doctor for treatment advice.
HOT LINE NUMBER	
Note to Physician	Probable mucosal damage may contraindicate the use of gastric lavage.
Have the product container or label with you when calling a poison control center or doctor, or going for treatment. For further information call National Pesticide Telecommunications Network (NPTN) at 1-800-858-7378.	

Net Contents: Two anti-foulant devices

Sea-Bird Electronics, Inc.
1808 - 136th Place Northeast
Bellevue, WA 98005

EPA Registration No. 74489-1
EPA Establishment No. 74489-WA-1

PRECAUTIONARY STATEMENTS

HAZARD TO HUMANS AND DOMESTIC ANIMALS

DANGER

Corrosive - Causes irreversible eye damage and skin burns. Harmful if swallowed. Harmful if absorbed through the skin or inhaled. Prolonged or frequently repeated contact may cause allergic reactions in some individuals. Wash thoroughly with soap and water after handling.

PERSONAL PROTECTIVE EQUIPMENT

USER SAFETY RECOMMENDATIONS

Users should:

- Remove clothing immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing.
- Wear protective gloves (rubber or latex), goggles or other eye protection, and clothing to minimize contact.
- Follow manufacturer's instructions for cleaning and maintaining PPE. If no such instructions for washables, use detergent and hot water. Keep and wash PPE separately from other laundry.
    - Wash hands with soap and water before eating, drinking, chewing gum, using tobacco or using the toilet.

ENVIRONMENTAL HAZARDS

Do not discharge effluent containing this product into lakes, streams, ponds, estuaries, oceans, or other waters unless in accordance with the requirements of a National Pollutant Discharge Elimination System (NPDES) permit and the permitting authority has been notified in writing prior to discharge. Do not discharge effluent containing this product to sewer systems without previously notifying the local sewage treatment plant authority. For guidance contact your State Water Board or Regional Office of EPA. This material is toxic to fish. Do not contaminate water when cleaning equipment or disposing of equipment washwaters.

PHYSICAL OR CHEMICAL HAZARDS

Do not use or store near heat or open flame. Avoid contact with acids and oxidizers.

DIRECTIONS FOR USE

It is a violation of Federal Law to use this product in a manner inconsistent with its labeling. For use only in Sea-Bird Electronics' conductivity sensors. Read installation instructions in the applicable Conductivity Instrument Manual.

STORAGE AND DISPOSAL

PESTICIDE STORAGE: Store in original container in a cool, dry place. Prevent exposure to heat or flame. Do not store near acids or oxidizers. Keep container tightly closed.

PESTICIDE SPILL PROCEDURE: In case of a spill, absorb spills with absorbent material. Put saturated absorbent material to a labeled container for treatment or disposal.

PESTICIDE DISPOSAL: Pesticide that cannot be used according to label instructions must be disposed of according to Federal or approved State procedures under Subtitle C of the Resource Conservation and Recovery Act.

CONTAINER DISPOSAL: Dispose of in a sanitary landfill or by other approved State and Local procedures.

Sea-Bird Electronics/label revised 01-31-05

Appendix V: Replacement Parts

Part Number	Part	Application Description	Quantity in 16*plus*
22018	Batteries, alkaline D-cell, Duracell MN 1300 (LR20)	Power 16*plus*	9
41124B	Battery cover plate	Retains batteries	1
801483	9D (10.8V / 42 amp-hour) lithium battery pack kit	For longer deployments; **batteries not included in kit, and not available from Sea-Bird**	-
801479	3DD (10.8V / 30 amp-hour) lithium battery pack kit	For longer deployments; **batteries not included in kit, and not available from Sea-Bird**	-
30411	Triton X-100	Octyl Phenol Ethoxylate – Reagent grade non-ionic cleaning solution for conductivity cell (supplied in 100% strength; dilute as directed)	1
801542	AF24173 Anti-Foulant Device	bis(tributyltin) oxide device inserted into anti-foulant device cup	1 (set of 2)
231505	Anti-foulant device cap	Secures AF24173 Anti-Foulant Device in cup	2
30984	Anti-foulant device plug	Seals end of anti-foulant assembly when not deployed	2
801225*	4-pin RMG-4FS to 9-pin DB -9S I/O cable, 2.4 m (8 ft) long	From SBE 16*plus* to computer	1
171888	25-pin DB-25S to 9-pin DB-9P cable adapter	For use with computer with DB-25 connector	-
17133*	2-pin RMG-2FS to 2-pin RMG-2FS cable, 1.1 m (3.7 ft.) long	From 16*plus* to optional pump	1
17044.1*	2-pin RMG-2FS dummy plug and locking sleeve	For when pump not used	1
17045.1*	3-pin RMG-3FS dummy plug and locking sleeve	For when optional PAR connector not used	-
17046.1*	4-pin RMG-4FS dummy plug and locking sleeve	For when I/O cable and/or optional RS-232 connector not used	1
17047.1*	6-pin AG-206 dummy plug and locking sleeve	For when auxiliary differential input sensors not used	2
801374	4-pin MCIL-4FS (wet-pluggable connector) to 9-pin DB-9S I/O cable, 2.4 m (8 ft) long	From 16*plus* to computer	1
171503	2-pin MCIL-2FS to 2-pin MCIL-2FS (wet-pluggable connector) cable, 1.1 m (3.7 ft) long	From 16*plus* to optional pump	1
171497.1	2-pin MCDC-2-F wet-pluggable dummy plug and locking sleeve	For when pump not used	1
171500.1	3-pin MCDC-3-F wet-pluggable dummy plug and locking sleeve	For when optional PAR connector not used	-
171398.1	4-pin MCDC-4-F wet-pluggable dummy plug and locking sleeve	For when I/O cable and/or optional RS-232 connector not used	1
171498.1	6-pin MCDC-6-F wet-pluggable dummy plug and locking sleeve	For when auxiliary differential input sensors not used	2
30388	Tygon tube, ½ inch ID x ¾ inch OD	Main plumbing tubing for pumped configuration	-
30579	Tygon tube, 3/8 inch ID x ½ inch OD	13 mm (0.5 inch) long pieces used for pumped configurations on conductivity cell exhaust cap and for SBE 43 intake and exhaust to fit to main plumbing	-
22009	Panasonic BR-2/3A lithium batteries	Back-up lithium cells on Power PCB	3

* For standard bulkhead connectors

continued on next page

continued from previous page

Part Number	Part	Application Description	Quantity in 16*plus*
60021	Spare battery end cap hardware and o-rings	O-rings and hardware, including: • 30145 Screw, 6-32 x 1/2 Phillips-head, stainless steel (secures battery cover plate to battery posts) • 30242 Washer, #6 flat, stainless steel (for 30145) • 30816 Parker 2-234E603-70 (battery end cap to housing piston seal, sensor end cap to housing seals) • 30090 Parker 2-153N674-70 (battery end cap to housing face seal)	-
50274	Spare o-ring kit	Assorted o-rings, including: • 30816 Parker 2-234E603-70 (battery end cap to housing piston seal, sensor end cap to housing seals) • 30090 Parker 2-153N674-70 (battery end cap to housing face seal) • 30507 Parker 2-206N674-70 (each end of conductivity cell) • 30802 Parker 2-110DUR070, ethylene (titanium conductivity cell tray face seal, groove surface) • 30809 Morrison seal, .047" hole, NIT (temperature probe Morrison seal) • 30072 Parker 2-017N674-70 (bulkhead connector seal) • 30070 Parker 3-904N674-70 (pressure sensor mounting seal) • 30087 Parker 2-232N674-70 (buffer for top retainer of PCB sandwich assembly) • 30801 Parker 5-374E603-70 (base of battery bulkhead seal)	-
50273	Spare hardware kit	Assorted hardware, including: • 30145 Screw, 6-32 x 1/2 Phillips-head, stainless steel (secures battery cover plate to battery posts) • 30242 Washer, #6 flat, stainless steel (for 30145) • 30414 Washer, #12, internal tooth (secures battery bulkhead retainer) • 30954 Screw 4-40 x 3/16 Phillips-head, stainless steel (securing screw for PCB retainer rod) • 31119 Screw 6-32 x 5/8 Truss Head (secures battery bulkhead retainer to bulkhead bottom plate) • 30176 Screw, 10-24 x 3/4, Phillips-head, stainless steel (secures Celcon threaded ring inside titanium battery end cap) • 30249 Washer #10, Flat, stainless steel (for 30176) • 30447 Bolt, ¼-20 x 1 ¼ Hex, titanium (secures lift eye to battery end cap) • 31089 Screw, 10-32 x 1/2 flat Phillips-head, titanium (secures sensor end cap to housing - side opposite conductivity cell guard) • 31090 Screw, 10-32 x 5/8 flat Phillips-head, titanium (secures conductivity cell guard to housing) • 31118 Screw, 10-32 x 3/8 Phillips-head, titanium (secures conductivity cell guard to sensor end cap) • 30875 Bolt ¼-20 x 5/8 Hex, titanium (secures connector guard to sensor end cap) • 30633 Washer, ¼" split ring lock, titanium (for 30875) • 30919 Screw, 6-32 x 3/8 flat slotted, titanium (secures anti-foulant device cup to conductivity cell guard) • 31066 Screw, 8-32 x ¾ socket, titanium (secures conductivity cell and TC duct to sensor end cap)	-
50276	Seaspares kit, standard connectors	Includes o-rings, hardware, bulkhead connectors, dummy plugs, etc.: • 50087 Conductivity cell filling and storage kit • 50273 Spare hardware kit (see above) • 50274 Spare o-ring kit (see above) • 41124B Battery cover plate • 801225 Data I/O cable, 4-pin RMG-4FS to 9-pin DB -9S I/O cable, 2.4 m (8 ft) long • 17044.1 2-pin RMG-2FS dummy plug with locking sleeve • 17046.1 4-pin RMG-4FS dummy plug with locking sleeve • 17047.1 6-pin AG-206 dummy plug with locking sleeve • 17652 2-pin XSG-2-BCL-HP-SS bulkhead connector • 17654 4-pin XSG-4-BCL-HP-SS bulkhead connector • 17628 6-pin AG-306-HP-SS bulkhead connector • 30388 Vinyl tube, ¾" x ½" (main sensor plumbing tubing) • 30409 Teflon tape (for insides of hose clamps) • 30411 Triton X100 (for cell cleaning) • 30457 Parker O-Lube (o-ring lubricant)	-

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Part Number	Part	Application Description	Quantity in 16*plus*
50301	Seaspares kit, wet-pluggable connectors	Includes o-rings, hardware, bulkhead connectors, dummy plugs, etc.: • 50087 Conductivity cell filling and storage kit • 50273 Spare hardware kit (see above) • 50274 Spare o-ring kit (see above) • 50275 Spare magnetic switch • 41124B Battery cover plate • 801374 Data I/O cable, 4-pin MCIL-4FS (wet-pluggable connector) to 9-pin DB-9S I/O cable, 2.4 m (8 ft) long • 171192 Locking sleeve • 171497 2-pin MCDC-2-F wet-pluggable dummy plug • 171398 4-pin MCDC-4-F wet-pluggable dummy plug • 171498 6-pin MCDC-6-F wet-pluggable dummy plug • 172019 2-pin MCBH-2MP(WB), TI ½-20 bulkhead connector • 172021 4-pin MCBH-4MP(WB), TI ½-20 bulkhead connector • 172022 6-pin MCBH-6MP(WB), TI ½-20 bulkhead connector • 171888 Cable adapter, DB-25F to DB-9M • 30388 Vinyl tube, ¾" x ½" (main sensor plumbing tubing) • 30409 Teflon tape (for insides of hose clamps) • 30411 Triton X100 (for cell cleaning) • 30457 Parker O-Lube (o-ring lubricant)	-

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